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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a reflecting triple grating type optical encoder which detects a position of an obj ect to be detected.

Description of the Related Art

[0002] An optical encoder which includes a detecting head and a scale are hitherto known (refer to Japanese Patent Application Laid-open Publication No. 2003-166856 for example). Fig. 21 shows an example of a structure disclosed in Japanese Patent Application Laid-open Publication No. 2003-166856. The documents WO 01/86232 and EP 0 672 891 also disclose such optical encoders. The detecting head includes a light source 14 in which a first grating 11 is disposed, and a photodetector 50 in which a third grating 30 is disposed. Moreover, a second grating 20 is formed on a scale 21. Light emerged from the light source 14 forms a self image on a light receiving surface of the photodetector 50 upon being affected by the first grating 11 and the second grating 20. In this patent application, "self image" means an optical pattern having a shape substantially similar to the second grating 20 formed on the light receiving surface of the photodetector 50. Moreover, the self image moves according to a relative displacement of the detecting head and the scale 21. The photodetector 50 detects the movement of the self image. Such type, hereinafter, will be called as a "reflecting triple grating type".

[0003] In the reflecting triple grating type optical encoder, it is desirable to perform a detection which is not affected easily by a change in a distance between the scale and the detecting head. For this, the first grating and the third grating included in the detecting head are disposed by lining up the heights thereof. Moreover, the self image can be classified into the following two typical cases (a) and (b) for example, according to structural conditions of the optical encoder, where case (a) is a case of having a same space period as of a shadow pattern of the second grating, and case (b) is a case of having the space period 1/2, 1/4, and ... of the shadow pattern of the second grating.

[0004] The most stable and the clearest image is formed in the case (a) mentioned above. Therefore, the case (a) mentioned above will be described below.

[0005] When the following conditional equation (1) is satisfied, a self image having the same space period as of the shadow pattern of the second grating is observed on the light receiving surface of the photodetector.

$$1/z1 + 1/z2 = \lambda/(k \times p2^2) \qquad \ldots(1)$$

where,
λ denotes a central wavelength of light emitted from the light source,
z1 denotes an optical distance between the first grating and the second grating,
z2 denotes an optical distance between the second grating and the third grating,
p2 denotes a pitch of the second grating, and
k denotes a natural number.

[0006] Here, when
Δ z0 is let to be a difference between z2 and z1, which is designed in advance,
Δ z is let to be a difference between z2 and z1 when actually manufactured, and
Δ zd is let to be a difference between Δz0 and Δz which occurred when actually manufactured (in other words, a difference between
Δ z0 designed in advance and Δz when actually prepared) the following equation (2) holds.

$$\Delta z = \Delta z0 + \Delta zd \qquad \ldots(2)$$

[0007] Inventors of this patent application performed the following experiment, and calculated a tolerance of Δzd required for achieving satisfactory signal strength by the photodetector. According to results of the experiment, it was revealed that, with predetermined conditions, to achieve the satisfactory signal amplitude at the photodetector, such as signal strength at which the maximum signal amplitude is 1/2 for example, the tolerance of Δzd is $\pm$36 μm. Moreover, it was revealed that with other conditions, for achieving the satisfactory signal strength at the photodetector, the tolerance of Δzd is approximately ± 33 μm.

[0008] Generally, the tolerance of machining accuracy is in a range of ± 50 μm to ± 100 μm. Therefore, from a point of view of manufacturing, it is extremely difficult to dispose by mounting the first grating, the second grating, and the third grating such that the Δzd is in a range of ± 36 μm to ± 33 μm. Moreover, when an attempt is made to realize an optical encoder in which Δzd is not greater than the range of ± 36 μm to ± 33 μm, a dimensional tolerance of structure members of the optical encoder being small, it becomes very difficult to manufacture at a low cost. Moreover, in the conventional example described above, a concrete method or a structure which is assembled with the tolerance Δzd to be very small is not at all disclosed.

SUMMARY OF THE INVENTION

[0009] The present invention is made in view of the aforementioned problems, and an object of the present invention is to realize a tolerance which makes the manufacturing easy by relaxing a tolerance of Δzd mentioned above, and to provide a triple grating type optical encoder which can be mass produced at a low cost.

[0010] To find a solution to the aforementioned issues, and to achieve the object, there can be provided an optical encoder according to claim 1.

[0011] In this optical encoder, the light projecting section is structured to irradiate the predetermined light by combining a light source and a first grating which is disposed on a side facing the scale with respect to the light source, and
an optical grating of a first pitch is formed in the first grating with respect to a direction of the relative displacement.

[0012] The photodetecting section is structured to detect the movement of the self image by combining the photodetector and a third grating which is disposed on the light receiving surface of the photodetector, and
an optical grating of a third pitch is formed in the third grating for the direction of the relative displacement.

[0013] Each of a formation surface of the first grating and a formation surface of the third grating is disposed substantially parallel with respect to the scale, and
in an optical path of light emitting from the light projecting section and reaching up to the photodetecting section upon being reflected and diffracted by the scale, a light transmitting area which is substantially flat and substantially parallel to the scale is formed on a surface of the detecting head facing the scale.

[0014] A light transparent member which has a refractive index greater than 1 is disposed in a space between the surface of the detecting head and the first grating, and in a space between the surface of the detecting head and the third grating.

[0015] Moreover according to a preferable aspect of the present invention, it is desirable that
the first grating includes an optical grating formed on a light transparent substrate, and
the light projecting section is structured by attaching the light transparent substrate to a light emitting surface of the light source.

[0016] Moreover according to another preferable aspect of the present invention, it is desirable that
the first grating is an optical grating formed directly on the light emitting surface of the light source, or an electrode pattern in the form of a grating which also serves as an electric current injecting electrode of the light source.

[0017] Furthermore, according to still another preferable aspect of the present invention, it is desirable that
the light source is a bare chip or a surface emitting semiconductor device in which the bare chip is seal-molded.

[0018] According to still another preferable aspect of the present invention, it is desirable that
at least one of the first grating and the third grating is an optical grating formed in the light transparent substrate, and
a side surface of the light transparent substrate is covered by a light transparent resin.

[0019] Moreover, according to still another preferable aspect of the present invention, it is desirable that
at least a space from the first grating and the third grating up to the surface of the detecting head is sealed by the light transparent resin.

[0020] Furthermore, according to still another aspect of the present invention, it is desirable that
a light transparent member in the form of a plate disposed parallel to the scale is disposed on a side facing the scale with respect to the first grating and the third grating, and
the light transparent substrate or a light transparent resin is disposed in a space between the light transparent member in the form of a plate and the first grating, and in a space between the light transparent member in the form of a plate and the third grating.

[0021] According to the present invention, there can be provided an optical encoder which includes
a scale which is installed on one of members of which a displacement is detected, and
a detecting head which is installed on other member which is displaced relatively with respect to the one of the members, and which is disposed facing the scale, where
the scale is provided with a second grating which has an optical pattern of a second pitch with respect to the direction of the relative displacement, and

the detecting head is provided with a light projecting section which irradiates a predetermined light on the scale, and a photodetecting section which detects a movement of a self image which is formed on a light receiving surface of a photodetector by light which is irradiated from the light projecting section to the scale, and which is reflected and diffracted by the second grating.

[0022] In this optical encoder, the light projecting section is structured to irradiate the predetermined light by combining a light source and a first grating which is disposed on a side facing the scale with respect to the light source, and an optical grating of a first pitch is formed in the first grating with respect to the direction of the relative displacement.

[0023] The photodetecting section is structured to detect the movement of the self image by a photodetector and at least one light receiving element array disposed on the photodetecting section.

[0024] The light receiving element array includes light receiving elements having a pitch of substantial integral multiples of a periodic intensity distribution of the self image, and each light receiving element in the light receiving element array is disposed by shifting through a fixed dimension in the direction of relative displacement, and
the light receiving surface and the formation surface of the first grating are disposed substantially parallel with respect to the scale, and
in an optical path of light emitting from the light projecting section and reaching up to the photodetecting section upon being reflected and diffracted by the scale, the light transmitting area which is substantially flat and substantially parallel to the scale is formed on the surface of the detecting head facing the scale.

[0025] The light transparent member which has a refractive index greater than 1 is disposed in the space between the surface of the detecting head and the first grating, and in the space between the surface of the detecting head and the light receiving element array.

[0026] Moreover, according to still another preferable aspect of the present invention, it is desirable that
the first grating includes an optical grating formed on a light transparent substrate, and
the light projecting section is structured by attaching the light transparent substrate to the light emitting surface of the light source.

[0027] Furthermore, according to still another preferable aspect of the present invention, it is desirable that the first grating is an optical grating formed directly on the light emitting surface of the light source, or an electrode pattern in the form of a grating which also serves as the electric current injecting electrode of the light source.

[0028] According to still another preferable aspect of the present invention, it is desirable that
the light source is a bare chip or a surface emitting semiconductor device in which the bare chip is seal-molded.

[0029] Moreover, according to still another preferable aspect of the present invention, it is desirable that
the first grating is an optical grating formed in the light transparent substrate, and
the side surface of the light transparent substrate is covered by a light transparent resin.

[0030] Furthermore, according to still another preferable aspect of the present invention, it is desirable that
at least the space from the first grating up to the surface of the detecting head, and the space from the light receiving element array up to the surface of the detecting head are sealed by a light transparent resin.

[0031] According to still another preferable aspect of the present invention, it is desirable that the light transparent member in the form of a plate disposed parallel to the scale is disposed on a side facing the scale with respect to the first grating and the light receiving surface, and
the light transparent substrate or a light transparent resin is disposed in the space between the light transparent member in the form of a plate and the first grating, and in a space between the light transparent member in the form of a plate and the light receiving surface.

[0032] Moreover, according to still another preferable aspect of the present invention, it is desirable that the light transparent member, a light transparent substrate, and a light transparent resin have a predetermined optical transmittance with respect to a predetermined wavelength region in which a light from the light source is emerged, and the optical transmittance is not greater than 1/2 with respect to at least one of a light of a wavelength side longer than the predetermined wavelength region, and a light of a wavelength side shorter than the predetermined wavelength region.

[0033] Furthermore, according to still another preferable aspect of the present invention, it is desirable that
a refractive index of the light transparent member is not less than 1.4 in a central wavelength of light emerged from the light source.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034]

Fig. 1 is a perspective view of a structure of an optical encoder according to a first embodiment of the present invention;
Fig. 2 is a cross-sectional view of the structure of the optical encoder according to the first embodiment;
Fig. 3 is a perspective view of a structure of an optical encoder used for an experiment;
Fig. 4 is a cross-sectional view of the structure of the optical encoder used for the experiment;

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0035] Embodiments of an optical encoder according to the present invention will be described below in detail with reference to accompanying diagrams. However, the present invention is not restricted to the embodiments described below.

[First embodiment]

[0036] Fig. 1 is a perspective view of a structure an optical encoder 100 according to a first embodiment of the present invention. Fig. 2 is a cross-sectional view of the structure of the optical encoder 100 according to the first embodiment. Firstly, the structure of the optical encoder 100 will be described. Further, an experiment related to a tolerance carried out by inventors of the present patent application will be described. Based on a result of the experiment, an action effect of the first embodiment will be described.

[0037] To start with, the structure of the optical encoder 100 according to the first embodiment will be described. A scale 121 having a flat and parallel form is disposed as one of members detecting a displacement. A second grating 120 is formed on a surface of the scale 121 towards a detecting head. The second grating 120 is an optical pattern formed by a second pitch p2 with respect to a direction along y axis in Fig. 1 and Fig. 2 for example, which is a direction of relative displacement of the scale 121 and a substrate 160 which will be described later.

[0038] Moreover, a bare chip LED 141 and a light transparent substrate 111 are stacked on the substrate 160. The substrate 160 corresponds to other member which is displaced relatively with respect to the scale 121. The bare chip LED 141 corresponds to a light source. A first grating 110 is formed on a surface of the light transparent substrate 111 on a side of the bare chip LED 141. The first grating 110 is an optical pattern formed by a first pitch p1 with respect to the direction along y axis in which the scale 121 and the substrate 160 are displaced relatively. A combination of the bare chip LED 141 and the first grating 110 corresponds to a light projecting section. Moreover, the bare chip LED 141 irradiates light of a wavelength λ = 650 nm for example.

[0039] A photodetector 150 and a light transparent substrate 131 are stacked on the substrate 160. A third grating 130 is formed on a surface of the light transparent substrate 131 on a side of the photodetector 150. The third grating 130 is an optical pattern formed by a third pitch p3 with respect to the direction along y axis in which the scale 121 and the substrate 160 are displaced relatively. A combination of the photodetector 150 and the third grating 130 corresponds to the photodetecting section. Further, a structure in which the projecting section and the photodetecting section are combined corresponds to the detecting head.

[0040] The photodetecting section which includes the photodetector 150 and the third grating 130 detects a movement of a self image which is formed on a light receiving surface of the photodetector 150 by light which is irradiated from the light projecting section to the scale 121, and which is reflected and diffracted by the second grating 120.

[0041] The bare chip LED 141, the light transparent substrate 111, the photodetector 150, and the light transparent substrate 131 which are disposed on the substrate 160 are embedded to be covered by a light transparent resin 190.

[0042] Each of a formation surface of the first grating 110 and a formation surface of the third grating 130, is disposed-parallel with respect to the scale 121. Moreover, in an optical path of light emittign from the light projecting section and reaching up to the photodetecting section upon being reflected and diffracted, a light transmitting area which is substantially flat and substantially parallel to the scale 121 is formed on a surface of the detecting head facing the scale 121. In other words, a surface of the light transparent resin 190 on a side of the scale 121 is formed to be substantially flat and substantially parallel with respect to the scale 121.

[0043] The scale 121 on which the second grating 120 is formed is disposed parallel to the first grating 110 and the third grating 130 such that the scale 121 is capable of a relative displacement in y direction. Here, a plane parallel to the formation surface of the first grating 110, the formation surface of the second grating 120, and the formation surface of the third grating 130 is let to be xy plane. Moreover, y direction is let to be a grating pitch direction of the second grating 120, x direction is let to be a direction perpendicular to the grating pitch direction of the second grating 120, and z direction is let to be a direction perpendicular to the xy plane.

[0044] An electrode pad 170 is formed on an upper surface of the bare chip LED 141. The electrode pad 170 on the bare chip LED 141 is connected to another electrode pad 170 on the substrate 160 via an electroconductive wire 171. Electrical wiring of the light source and the photodetector is omitted in Fig. 1 and Fig. 2.

(Experiment related to tolerance of grating position)

[0045] Next, an experiment related to a tolerance of mutual positions of the first grating 110, the second grating 120, and the third grating 130 which was carried out by inventors of the present patent application will be described.

[0046] A case of observing an optical pattern substantially similar to the second grating 120 formed on the light receiving surface of the photodetector 150, in other words, a case of observing the self image is taken into consideration. An intensity distribution period p33 of the self image on the light receiving surface of the photodetector 150 becomes,

$$p33 = p2 \times (z1 + z2) / z1 \qquad \ldots(3)$$

$$= p2 \times (2 + \Delta z/z1) \qquad \ldots(4)$$

Here, Δz was let to be

$$\Delta z = z2 - z1 \qquad \ldots(5)$$

[0047] Therefore, it is desirable to match the third pitch p3 of the third grating 130 with the intensity distribution period p33 of the self image, or to make a multiple thereof. Accordingly, when the scale 121 is displaced, the movement of the self image on the light receiving surface can be captured with the maximum amplitude.

[0048] In other words, by setting

$$p3 = p33 \times m \qquad \ldots(6)$$

the maximum signal amplitude from the photodetector 150 is obtained. Here, m is a natural number.

[0049] Furthermore, froman optical symmetryproperty of the first grating 110 and the third grating 130, the optimum period p1 of the first grating 110 for forming a clear self image is

$$p1 = p2 \times (z1 + z2) / z2 \qquad \ldots(7)$$

$$= p2 \times (2 - \Delta z/z2) \qquad \ldots(8)$$

[0050] Furthermore, when

Δ z0 is let to be a difference between z2 and z1, which is designed in advance,
Δ z is let to be a difference between z2 and z1 when actually manufactured, and
Δ zd is let to be a difference between Δz0 and Δz which occurred when actually manufactured (in other words, a difference between
Δ z0 designed in advance and Δz when actually prepared), the following equation (2) holds.

$$\Delta z = \Delta z0 + \Delta zd \qquad \ldots(2)$$

[0051] Particularly, when z1=z2, in other words, in a structure where Δz=0 in Fig. 21 which is an example of the conventional technology,

$$2 / z1 = \lambda / (n \times p2^2) \qquad \ldots(9)$$

$$p1 = p33 = 2 \times p2 \qquad \ldots(10)$$

[0052] Therefore, the first pitch p1 of the first grating 110, the second pitch p2 of the second grating 120, and the third pitch p3 of the third grating 130 may be set in advance such that p1 = p3 = 2 $\times$ p2. When the relation becomes p1 = p3 = 2 $\times$ p2, it is easy to design each pitch of the first grating 110, the second grating 120, and the third grating 130.

[0053] Generally, Δz = 0, in other words, z1 = z2, is not an essential condition. In this case, for a value of Δz0 set in advance, each of structural parameters λ, z1, z2, p1, p2, and p3 may be set in advance based on equations (1) to (8).

[0054] Moreover, when z1 and z2 are disposed with a value different from the set value, in other words, when Δzd $\neq$ 0, in conjunction with this, the values Δz/z1 and Δz/z2 in equations (4) and (8) change. Therefore, the optimum value of p1 and p3 is changed from the value set in advance. This is because the pitch p3 of the third grating and the intensity distribution period p33 of the self image are mismatched, and a value of the optimum pitch p1 of the first grating which forms the clear self image is changed.

[0055] Therefore, when Δzd $\neq$ 0, in other words, when z1 and z2 are disposed with the set value mismatched, signal amplitude from the photodetector 150 is decreased. Therefore, disposing z1 and z2 by taking as close as possible to the set value, in other words, making Δzd which occurs during manufacturing, as small as possible, and manufacturing the first grating 110 and the third grating 130 such that there is no variation from the set height, is a point in realizing a high-performance encoder.

[0056] The inventors of the present invention carried out an experiment about a relation of Δzd and the signal amplitude from the photodetector 150 for a structure in Fig. 3 and Fig. 4, to find the tolerance of Δzd for a reflecting triple grating type optical encoder.

[0057] A structure of an encoder used in the experiment will be described with reference to Fig. 3 and Fig. 4. The bare chip LED 141 and the light transparent substrate 111 on which the first grating 110 is formed are stacked on a substrate 161. The photodetector 150 and the light transparent substrate 131 on which the third grating 130 is formed are stacked on a substrate 162 which is a substrate apart from the substrate 161.

[0058] On the other hand, the scale 121 on which the second grating 120 is formed, is disposed parallel to the formation surface of the first grating 110 and the formation surface of the third grating 130. Here, the plane parallel to each of the formation surfaces of the first grating 110, the second grating 120, and the third grating 130 is let to be xy plane. Moreover, y direction is let to be the grating pitch direction of the second grating 120, x direction is let to be the direction perpendicular to the grating pitch direction of the second grating 120, and z direction is let to be the direction perpendicular to the xy plane. A light transmission plate 105 shown in Fig. 3 is to be neglected in the description of this experiment.

[0059] When the scale 121 is displaced in y direction, the self image described above is moved in y direction on the formation surface of the third grating 130. Accordingly, a periodic quasi-sinusoidal waveform signal is obtained from the photodetector 150. According to a result of the experiment, an amplitude of the periodic quasi-sinusoidal waveform signal changed as shown in Fig. 5 when Δzd was changed.

[0060] A horizontal axis in Fig. 5 denotes Δzd (unit: mm), and a vertical axis denotes the signal amplitude (unit: arbitrary, normalized with the maximum value). Experiment conditions are λ = 650 nm, p2 = 20 μm, and n = 1.

[0061] Moreover,
an effective area of the first grating 110 is let to be 0.15 mm $\times$ 0.15 mm
(in Fig. 3, $W_{x,1} = W_{y,1}$ = 0.15 mm) , and

an effective area of the third grating 130 is let to be 1.0 mm × 0.5 mm (in Fig. 3, $W_{x, 3}$ = 0.5 mm and $W_{y, 3}$ = 1.0 mm) .

[0062] First of all, for each case for which Δz0 is set to be Δ z0 = 0 and Δz0 = 0.03, initially z1 and z2, and p1 and p3 are determined by equations (1) to (8). Next, z1 is kept constant and z2 is changed. Accordingly, the height of the first grating 110 and the third grating 130 is changed and the signal amplitude obtained from the photodetector 150 is measured.

[0063] According to the experiment result, when p1, p3, z1, and z2 are set to have optimum condition with Δz0 = 0, a result denoted by a curve L1 in Fig. 5 (continuous line) is obtained. In the curve L1, the tolerance of Δzd at which the signal amplitude becomes 1/2 is approximately ±36 μm.

[0064] Moreover, in an experiment in which the maximum amplitude is obtained when Δz0 = 0.03 mm, a value of the tolerance of Δzd achieved is ±33 μm. In other words, when Δz0 = 0.03 mm, it is necessary to contain the value of Δz to be about 0.03 mm ± 33 μm.

[0065] As it is clear from the result, with the typical experiment conditions mentioned above, the first grating 110, the second grating 120, and the third grating 130 are required to be disposed by mounting such that Δzd is not greater than ±36 μm to ±33 μm.

(Action and effect of first embodiment)

[0066] Next, an action and an effect of the first embodiment will be described. Thus, according to the result of the experiment, the first grating 110, the second grating 120, and the third grating 130 are required to be disposed by mounting such that Δ zd is not greater than ±36 μm to ±33 μm. Whereas, as mentioned above, a normal tolerance of machining accuracy is in a range of about ±50 μm to ±100 μm. Therefore, from a manufacturing point of view, it is extremely difficult to dispose by mounting the first grating 110, the second grating 120, and the third grating 130 such that Δzd is not greater than ±36 μm to ± 33 μm.

[0067] First of all, to explain the effect of the first embodiment, further experiment was carried out by using the optical encoder of the first embodiment described in Fig. 1 and Fig. 2. An optical encoder having a different Δz (height of the first grating 110 and the third grating 130) shown in Fig. 2 is prepared by changing a thickness of the photodetector 150. For each one, an entire detecting head is filled with a light transparent resin having a refractive index of approximately 1.6, and sealed.

[0068] p1, p3, z1, and z2 are set to have the optimum conditions with Δz0 = 0, and the signal amplitude obtained from the photodetector for a detecting head having a different Δz is denoted by curve L2 in Fig. 5 (denoted by alternate long and short dash line) . As it is clear from Fig. 5, when the entire detecting head is filled with the light transparent resin 190 and sealed, the tolerance of Δzd for which the signal amplitude is 1/2 is approximately ±62 μm. It is revealed that the tolerance is relaxed (becomes large) by approximately 1. 7 times as compared to a case in air mentioned above (curve L1 in Fig. 5).

[0069] Next, a result of a supplementary experiment carried out for considering a basic principle of relaxing of the tolerance of Δzd will be described. In this supplementary experiment, in a structure shown in Fig. 4, by changing a thickness t of the light transmission plate 105, the optimum designing of the pitch p1 and p3 for a case of Δzd = 0 was performed, and a value of z1 (= z2) at which the signal amplitude becomes the maximum was measured.

[0070] Accordingly, when the thickness of the light transmission plate 105 is let to be t, the refractive index of the light transmission plate 105 is let to be nindex, and the refractive index in the air is let to be 1, when the light transmission plate 105 is there, it was observed that the value of z1 and z2 at which the maximum wavelength can be achieved is increased by t × (nindex - 1) as compared to when the light transmission plate 105 is not there.

[0071] In other words, when a space in an optical path of an optical ray is filled with a member having a refractive index nindex, the value of z1 and z2 in equations (1), (3), (4), (7), and (8) may be considered to be 1/nindex times with respect to a geometric dimension for a portion which is the member having the refractive index nindex. Thus, it was revealed that it is necessary to have a way of thinking different from a common sense for a normal optical path length (optical path length becomes nindex times of the geometric dimension). It has been confirmed by an observation of the intensity distribution on the light receiving surface that the amplitude of spatial intensity distribution of the self image of the scale 121 and the second grating 120 is hardly changed according to a presence or an absence of the light transmission plate 105.

[0072] Therefore, when the light transparent member having a refractive index nindex is filled in the optical path of light emittign from the projecting section, reflected and diffracted at the scale 121, and reaching the photodetecting section, a rate of change of the optimum value of the pitch p1 and p3 determined by equations (4) and (8) is considered to be 1/nindex as compared to a case in the air.

[0073] A distance between the surface of the detecting head on the light projecting section and the formation surface of the second grating 120 is let to be z10 and the distance between a surface of the detecting head on the photodetecting section and the formation surface of the second grating 120 is let to be z20. At this time, in the first embodiment, in the optical path of light the light emerged from the light projecting section and reached up to the photodetecting section upon being reflected and diffracted by the scale 121, a light transmitting area which is substantially flat and substantially parallel to the scale 121 is formed on the surface of the detecting head facing the scale 121.

[0074] Therefore a difference between z20 and z10 is considered to have very small variation from a designed value. Therefore, Δ zd mentioned above is determined by the following two factors (a) and (b).

(a) A manufacturing variability of a difference in the height of the first grating 110 and the height of the third grating 130

(b) A refractive index of a space between the surface of the detecting head on the light projecting section and the first grating 110, and between the surface of the detecting head on the photodetector and the third grating 130.

[0075] As a result, when the space between the surface of the detecting head on the light projecting section and the first grating 110, and between the surface of the detecting head on the photodetector and the third grating 130 is filled by the member having the refractive index nindex, a tolerance of the manufacturing variability in difference of the height of the first grating 110 and the height of the third grating 130 is increased by nindex times.

[0076] A normal light transparent member has a refractive index not less than 1, glass has a refractive index of about 1.5 and a light transparent resin has a refractive index of about 1.4 to 2 for example. Therefore, when the glass or the light transparent resin is used, the tolerance of the heights of the first grating 110 and the third grating 130 is relaxed by about 1. 4 to 2 times. This is a reason for the tolerance of Δzd relaxed when the entire detecting head is filled with the light transparent resin 190 and sealed. Moreover, it is desirable that the refractive index of the light transparent member is not less than 1.4 in the central wavelength of light emerged from the light source. It is desirable for all embodiments that the refractive index of the light transparent member is not less than 1.4.

[0077] In the first embodiment, in the optical path of light emitting from the light projecting section and reaching up to the photodetecting section upon being reflected and diffracted by the scale 121, the light transmitting area which is substantially flat and substantially parallel to the scale 121 is formed on the surface of the detecting head facing the scale 121. Moreover, the light transparent resin 190 which is a light transparent member is disposed in the space between the surface of the detecting head and the first grating 110, and in the space between the surface of the detecting head and the third grating 130. Therefore, a dimensional tolerance and a mounting tolerance of the structure member are relaxed (becomes large). As a result of this, the optical encoder 100 can be mass produced at a low cost.

[0078] Thus, in the first embodiment, by the structure described in Fig. 1 and Fig. 2, a required accuracy of the tolerance Δzd is relaxed. Light emerged from the bare chip LED 141 is irradiated on the second grating 120 on the scale 121 via the light transparent substrate 111 on which the first grating 110 is formed. Light reflected and diffracted at the second grating 120 is reached to the photodetector 150 via the light transparent substrate 131 on which the third grating 130 is formed.

[0079] Here, when structural parameter of each element becomes a value which is set in equation (1) as an approximate value, a self image of the scale 121 with the space period p33 regulated by equation (3) is formed on the formation surface (hereinafter, called as "light receiving surface" when deemed appropriate) of the third grating 130. When the scale 121 is displaced relatively in y direction, the self image is moved in y direction. Therefore, a periodic quasi-sinusoidal waveform signal is obtained from the photodetector 150.

[0080] Each member disposed on the substrate 160 is embedded in the light transparent resin 190. Therefore, there is an advantage that a tolerance of a height difference between the first grating 110 and the third grating 130 is increased by the portion of the refractive index of the light transparent resin 190.

[0081] Moreover, side surfaces of the light transparent substrates 110 and 131 on which the first grating 110 and the third grating 130 are formed respectively are embedded in the light transparent resin 190. Therefore, a reflection at a side surface of light beams denoted by light beams 181 and 182 which are generated when the light transparent resin is not there is suppressed, and becomes as the light beams 181 and 182 shown in Fig. 2. Accordingly, light beams emerged from the light source can be guided efficiently to the photodetector 150. As a result of this, the signal amplitude of the photodetector 150 is increased and effects such as improvement in S/N as a sensor, achieving high resolution of position detection, and improvement in noise resistant property are shown. Particularly, when an angle formed by a light beam directed from the light source to the scale 121 and a side surface of the light transparent substrate 111, shown by the light beam 181, or an angle formed by a light beam directed from the scale 121 to the photodetector 150 and a side surface of the light transparent substrate 131 shown by the light beam 182, becomes a critical angle of total internal reflection, a light component along this light beam is not transmitted at all. Therefore, according to a disposing condition of component members, the signal amplitude can be improved remarkably. The reason for the light reflection being suppressed at the side surface of the light transparent substrate 111 and 131, is that a difference between the refractive index of the light transparent substrates 111 and 131, and the refractive index of the light transparent resin 190 is smaller than a difference between the refractive index of the light transparent substrate 111 and 131, and the refractive index of air. Moreover, the critical angle of total internal reflection is determined by a difference in refractive index of the light transparent substrates 111 and 131, and a refractive index of a member in contact with the light transparent substrates 111 and 113, and smaller the difference in the refractive indices, the angle of total internal reflection increases, and the total internal reflection does not occur.

[0082] Moreover, by sealing the detecting head by a resin, reliability with respect to humidity and dirt etc. can be improved. Furthermore, in the first embodiment, by sticking the light transparent substrate 111 on which the first grating 110 is formed, directly to the light source, the manufacturing of the light projecting section becomes easy. By using the bare chip LED 141 as the light source, the light projecting section can be manufactured to be thin and at a low cost.

(Modified embodiments)

[0083] Each component member of the first embodiment can be transformed and modified into various types. For example, in the first embodiment, a case in which the bare chip LED is used as the light source is shown. However, the light source is not restricted to the bare chip LED, and may be any one such as a normal LED molded component and a surface emitting laser, which can form a self image.

[0084] Moreover, a case in which the third grating 130 is a group of gratings was described. However, the third grating 130 also includes a structure in which a plurality of grating group is disposed by shifting phases thereof, and a photodetector is disposed for each of the grating. Furthermore, a structure in which the second grating 120, the first grating 110, and the third grating 130 on the scale 121 are at a constant period, and a structure in which an amount of relative displacement is detected was described. However, an optical pattern for detecting a reference position can also be disposed near each of the first grating 110, the second grating 120, and the third grating 130. Moreover, a one-dimensional grating pattern of the first grating 110, the second grating 120, and the third grating 130 is described. However, a structure in which the gratings are formed in a two-dimensional form, and a two-dimensional displacement is detected is also possible.

[0085] Moreover, in Fig. 1 and Fig. 2, the surface on which the first grating 110 is formed on the light transparent substrate 111 is let to be a surface facing the bare chip LED 141. The surface on which the third grating 130 is formed on the light transparent substrate 131 is let to be a case of a surface facing the photodetector 150. However, the present invention is not restricted to this, and the first grating 110 and the third grating 130 formed on the light transparent substrate 111 and the light transparent substrate 131 respectively, may be formed on a surface facing the scale 121.

[0086] Moreover, any method can be used for covering a surrounding of the detecting head by the light transparent resin 190. For example, methods such as a method of dispensing the light transparent resin 190 corresponding to each detecting head, a method of applying a light transparent resin on an entire surface of a large size after mounting component members of several detecting heads on the large size substrate, and after curing (hardening) the resin, and isolating into individual detecting head by dicing, are available.

[0087] Moreover, regarding a method of making flat the surface of the light transparent resin 190 facing the scale 121, any method such as a resin mold method, a method of making the surface substantially flat by a surface tension, and a method of polishing after coating can be applied.

[Second embodiment]

[0088] Fig. 6 is a perspective view of a structure of an optical encoder 200 according to a second embodiment of the present invention. Fig. 7 is a cross-sectional view of the structure of the optical encoder 200 according to the second embodiment of the present invention. The second embodiment differs from the first embodiment at points that in the second embodiment, each of the projecting section in which the bare chip LED 141 and the first grating 110 are stacked, and the photodetecting section in which the photodetector 150 and the third grating 130 are stacked, is covered by a light transparent resin 290a and a light transparent resin 290b which are different. The same reference numerals are used for components which are same as in the first embodiment and their description is omitted to avoid repetition.

[0089] In the second embodiment, the light transparent resin 290a covers an optical path from the bare chip LED 141 up to the scale 121. Moreover, the light transparent resin 290b covers an optical path from the scale 121 up to the photodetector 150. Thus, light transparent resin 290a and the light transparent resin 290b may be ensured to have flatness only in an area through which the respective light passes.

[0090] Therefore, for example, even if a member or a manufacturing method in which the flatness of the light transparent resin is difficult to be ensured, is used, as compared to forming integrally a large light transparent resin as in the first embodiment, in the optical path from the bare chip LED 141 up to the photodetector 150 via the scale 121, it is easy to form an upper surface of the detecting head flat.

[0091] Moreover, each of the side surfaces of the light transparent substrates 111 and 131, is covered by the light transparent resin 290a and the light transparent resin 290b respectively. Accordingly, a surface in contact with the air is away from a light emitting portion of the bare chip LED 141. As a result of this, an effect in which, the total internal reflection of light emerged from the bare chip LED 141 at the side surface of the light transparent substrates 111 and

131 can be reduced, is shown. Actions other than this are similar to actions in the first embodiment. Moreover, each structure of the second embodiment can be transformed and modified into various types of structures similarly as in the first embodiment.

[Third embodiment]

[0092] Fig. 8 shows a perspective view of a structure of an optical encoder 300 according to a third embodiment of the present invention. Fig. 9 shows a cross-sectional view of the structure of the optical encoder 300 according to the third embodiment. The third embodiment differs from the first embodiment at a point that in the third embodiment, a plurality of periodic rectangular openings (apertures) of the first pitch (period) p1 described above is formed on an electrode 143 in the form of a grating on the upper surface of the bare chip LED 141. The same reference numerals are used for components same as in the first embodiment, and the description is omitted to avoid repetition.

[0093] The periodic openings (apertures) of the electrode 143 in the form of a grating of the bare chip LED 141 show a function similar to a function of the first grating 110. According to this structure, in addition to the effect of the first embodiment, there is an advantage that a process of stacking the bare chip LED 141 and the first grating 110 can be omitted, thereby making the manufacturing easy. Moreover, the light projecting section can be structured to be thin. Each structure of the third embodiment can be transformed and modified into various types of structures similarly as in the first embodiment.

[Fourth embodiment]

[0094] Fig. 10 shows a perspective view of a structure of an optical encoder 400 according to a fourth embodiment of the present invention. Fig. 12 shows a cross-sectional view of the structure of the optical encoder 400 according to the fourth embodiment. The fourth embodiment differs from the first embodiment at a point that in the fourth embodiment, the photodetector is let to be a light receiving element array formed with the third pitch (period) p3 as shown in Fig. 11. The same reference numerals are used for components same as in the first embodiment, and the description of these components is omitted to avoid repetition.

[0095] Fig. 11 shows an enlarged view of a light receiving element array 151 formed on the photodetector 150. The light receiving element array 151 includes a plurality of sets of four photodiodes PD1, PD2, PD3, and PD4 having a rectangular shape, combined together.

[0096] The photodiodes PD1, PD2, PD3, and PD4 are disposed in the form of comb teeth, each shifted through 1/4 $\times$ p3. Moreover, an electric signal from each of the photodiodes PD1, PD2, PD3, and PD4 is output from four electrode pads A1, B1, A2, and B2.

[0097] When the scale 121 is displaced relatively in y direction, quasi-sinusoidal sine wave signals having a phase differed by only 1/4 period are obtained from the four electrode pads A1, B1, A2, and B2. Accordingly, it is possible to detect a direction of displacement (distinction of a direction of movement). Furthermore, by performing an interpolation treatment of the output signal (interpolation treatment of displacement amount), it is possible to detect an amount of displacement by a resolution which is significantly minute than the second pitch of the second grating 120 formed on the scale 121.

[0098] Even in the first embodiment, a similar effect in principle is possible by disposing a plurality of sets of the third grating 130 and the photodetector 150. Here, in the fourth embodiment, the plurality of photodiodes PD1, PD2, PD3, and PD4 having a different phase can be disposed at substantially the same position. Therefore, it is possible to relax significantly a rotational tolerance in the plane as compared to a case in which the plurality of sets of the third grating 130 and the photodetector 150 is positioned at different positions. Furthermore, the light transparent substrate on which the third grating 130 is formed is not required to be mounted. Therefore, in the fourth embodiment, a function of the third grating 130 can be realized easily with high accuracy and at further lower cost.

[0099] Even in the fourth embodiment, as a matter of course, various transformations and modifications are possible. The pitch of the photodiodes PD1, PD2, PD3, and PD4 may also be in integral multiples of P3. Moreover, amount through which each of the photodiodes PD1, PD2, PD3, and PD4 is shifted (shifting amount) is not restricted to 1/4 $\times$ p3, and various configurations such as three sets having the shifting amount 1/3 $\times$ p3 (three sets of photodiodes), four sets having the shifting amount 3/4 $\times$ p3 (four sets of photodiodes), and m sets having the shifting amount 1/m $\times$ p3 (where m is a natural number, and m sets of photodiodes).

[Fifth embodiment]

[0100] Fig. 13 shows a perspective view of a structure of an optical encoder 500 according to a fifth embodiment of the present invention. Fig. 14 shows a cross-sectional view of the structure of the optical encoder 500 according to the fifth embodiment. In the fifth embodiment, a resin mold LED 144 is used as the light source of the light projecting section.

In the resin mold LED 144, the electrode pad 170 on the upper surface of the bare chip LED 141 is connected to the electrode pad 171 on a lower surface of the resin mold LED 144 by the electroconductive wire 171. Moreover, the other electrode pad 170 of the bare chip LED 141 is connected directly to the electrode pad 170 on a lower surface of the resin mold LED 144 by a material such as a solder material. Furthermore, the light transparent substrate 111 on which the first grating 110 is formed is stacked on an upper surface of the resin mold LED 144. The rest of the structure is similar to the structure in the fourth embodiment.

[0101] The basic action of the fifth embodiment is similar to the basic action of the fourth embodiment. By replacing the bare chip LED by the resin mold LED 144, there is some increase in a thickness and planar dimensions of the light projecting section. However, a size of the substrate on which the first grating 110 is formed is increased, thereby easing the handling, and a bonding pad of the conductive wire disposed on the upper surface of the bare chip LED is not required. Accordingly, there is an advantage that the mounting of the light transparent substrate 111 on which the resin mold LED 144 and the first grating 110 are formed becomes easy.

[0102] Generally, a tolerance for variation in a height of the resin mold LED 144 is about $\pm 60\ \mu m$. According to the structure of the fifth embodiment, when the refractive index of the light transparent resin 190 is let to be nindex, the tolerance for variation in the height of the resin mold LED 144 can be reduced to 1/nindex. For example, when nindex is let to be 2 (nindex = 2), the tolerance for the variation in the height of the resin mold LED 144 is equal to about $\pm 30\ \mu m$ which is a value when disposed in the air. Therefore, even when the resin mold LED 144 having the tolerance for variation in the height $\pm 60\ \mu m$ is used, it is possible to realize a range of tolerance of the experiment result mentioned above.

[0103] Each structure of the fifth embodiment can be transformed and modified to various structures. For example, the upper surface of the resin mold LED 144 is not required to be flat entirely, and a joining portion of the light transparent substrate 111 on which the first grating 110 is formed may be let to be flat.

[0104] Moreover, a concavity and convexity having a function of a lens may be formed on a portion other than the flat area on the surface of the resin mold LED 144. Accordingly, it is also possible to control an angle of irradiation of the light beam such that the light beam is guided effectively to the photodetector 150.

[Sixth embodiment]

[0105] Fig. 15 shows a perspective view of a structure of an optical encoder 600 according to a sixth embodiment of the present invention. Fig.16 shows a cross-sectional view of the structure of the optical encoder 600 according to the present invention. In the sixth embodiment, the structure of the light projecting section is formed identically as in the third embodiment, and the photodetecting section is formed identically as in the fourth embodiment.

[0106] An action of the light projecting section is the same as an action of the light projecting section in the third embodiment. Moreover, an action of the photodetecting section is same as an action of the photodetecting section in the fourth embodiment. Therefore, the light transparent substrates 111 and 131 on which the first grating 110 and the third grating 130 are formed are not required to be mounted. Accordingly, it is possible to realize a function of the first grating 110 and the third grating 130 with high accuracy and at low cost. Each structure of the sixth embodiment can be transformed and modified into various types of structures. Examples of transformation are similar as in the third embodiment and in the fourth embodiment.

[Seventh embodiment]

[0107] Fig. 17 shows a cross-sectional view of a structure of an optical encoder 700 according to a seventh embodiment of the present invention. In the seventh embodiment, in the light projecting section, a light transparent substrate 791 on which a first grating 143 is formed is stacked on the upper surface of the resin mold LED 144, and the light receiving element array 151 is used in the photodetecting section.

[0108] In the seventh embodiment, instead of forming the light transparent resin so as to cover the entire light projecting section and the photodetecting section, a light transparent member 791 in the form of a plate is disposed on an upper portion of the light projecting section and the photodetecting section, such that the light transparent member 791 faces in parallel with a surface of the scale 121. Moreover, it is a structure in which a light transparent resin 790 is disposed in a gap developed by a difference in a height of the light projecting section and a height of the photodetecting section. The light transparent resin 790 may be allowed to have a function of an adhesive.

[Modified embodiments]

[0109] Fig. 18 shows a cross-sectional view of a structure of an optical encoder 750 according to a modified embodiment of the seventh embodiment. Fig. 17 is an example of a structure in which the light transparent resin 790 is disposed between the light receiving element array 151 (third grating) and the light transparent member 791 in the form of a plate.

Whereas, the modified embodiment of the seventh embodiment is an example in which, the light transparent resin 790 is disposed between the electrode 143 in the form of a grating (first grating) and the light transparent member 791 in the form of a plate. The rest of the structure is similar to the structure in the first embodiment.

[0110] The light transparent resin 790 is disposed between the electrode 143 in the form of a grating (first grating) and the light transparent member 791 in the form of a plate, or between the light receiving element array 151 (third grating) and the light transparent member 791 in the form of a plate. Therefore, it is possible to have a substantial tolerance of height of disposing of the electrode 143 in the form of a grating (first grating) and the light receiving element array 151 (third grating).

[0111] Each structure of the modified embodiment of the seventh embodiment can be transformed and modified into various types of structures. Space to be embedded (filled) by the light transparent resin 791 need not necessarily be restricted to the gap between the electrode 143 in the form of a grating (first grating), the light receiving element array 151 (third grating), and the light projecting section and the photodetecting section. For example, a structure in which a side surface of the light projecting section and the photodetecting section are embedded may also be used. Other modified embodiments are similar to the fifth embodiment and the sixth embodiment for example.

[Eighth embodiment]

[0112] Fig. 19 shows a cross-sectional view of a structure of an optical encoder 800 according to an eighth embodiment of the present invention. The eighth embodiment is similar to the first embodiment except for the structure of the light projecting section and the photodetecting section, in which the resin mold LED is used instead of the bare chip LED.

[0113] Moreover, instead of forming the light transparent resin 190 so as to cover the entire light projecting section and the photodetecting section, light transparent members 891a, 891b, and 891c in the form of a plate are disposed on the upper portion of the light projecting section and the photodetector 150, such that the light transparent members face in parallel with the surface of the scale 121. Moreover, it is a structure in which a light transparent resin 890 is disposed in the gap developed by a difference in the height of the light projecting section and the height of the photodetector 150. The light transparent resin 890 may be allowed to have the function of an adhesive.

(Modified embodiment)

[0114] Fig. 20 shows a cross-sectional view of a structure of an optical encoder 850 according to a modified embodiment of the eighth embodiment. In the modified embodiment of the eighth embodiment, light transparent members 991a, 991b, and 991c in the form of a plate are disposed. The modified embodiment of the eighth embodiment is an example of a structure in which a light transparent resin 990 is disposed between the first grating 110 and the light transparent member 991b in the form of a plate. The rest of the structure is similar to the structure in the first embodiment.

[0115] In the eighth embodiment and the modified embodiment of the eighth embodiment, the light transparent resins 890 and 990 are disposed between the first grating 110 and the light transparent member 991b in the form of a plate, or between the third grating 130 and the light transparent member 891b in the form of a plate. Therefore, it is possible to have a substantial tolerance of height of disposing the first grating 110 and the third grating 130.

[0116] Each structure of the modified embodiment of the eighth embodiment can be transformed and modified into various types of structures. Space to be embedded (filled) by the light transparent resins 890 and 990, need not necessarily be restricted to the gap between the first grating 110, the second grating 130, and the light projecting section and the photodetector. For example, a structure in which the side surface of the light projecting section and the photodetecting section are embedded may also be used. Other modified embodiments are similar to the first embodiment for example.

[0117] Moreover, in each of the embodiments described above, the structure can be let to be the following structures (1), (2), and (3).

(1) A structure in which a wavelength of the light source is set in a region of ultraviolet light or visible light, the light transparent member, the light transparent substrate, and the light transparent resin have an optical transparency for the wavelength of the light source, but the optical transmittance for infra-red light is not more than 1/2.

(2) A structure in which the wavelength of the light source is set in a region of ultraviolet light or infra-red light, the light transparent member, the light transparent substrate, and the light transparent resin have the optical transparency for the wavelength of light source, but the optical transmittance for the visible light is not more than 1/2.

(3) A structure in which the wavelength of the light source is set in a region of the visible light or the infra-red light, the light transparent member, the light transparent substrate, and the light transparent resin have the optical transparency for the wavelength of light source, but the optical transmittance for the ultraviolet light is not more than 1/2.

[0118] Thus, the light transparent member and the light transparent resin may be let to be a member and a resin which have the optical transparency for the wavelength of the light source, and may not be let to have the optical transparency for a wavelength other than the wavelength of the light source. When the wavelength of the light source is set in the region of the ultraviolet light or the visible light for example, the light transparent member, the light transparent substrate, and the light transparent resin have the optical transparency for the wavelength of the light source, but may be let to have a less optical transmittance for the infra-red light. Accordingly, in an environment of substantial infra-red light, sensing in which an effect due to the infra-red light is suppressed is possible.

[0119] Moreover, when the wavelength of the light source is set in the region of the ultraviolet light or the infra-red light, the light transparent member, the light transparent substrate, and the light transparent resin have the optical transparency for the wavelength of the light source, but may be let to have a less optical transmittance for the visible light. Accordingly, in an environment of substantial visible light, a sensing in which an effect due to the visible light is suppressed is possible.

[0120] Furthermore, when the wavelength of the light source is set in the region of the visible light or the infra-red light, the light transparent member, the light transparent substrate, and the light transparent resin have the optical transparency for the wavelength of the light source, but may be let to have a less optical transmittance for the ultraviolet light. Accordingly, in an environment of substantial ultraviolet light, a sensing in which an effect due to the ultraviolet light is suppressed is possible.

[0121] Moreover, it is needless to say that the structures in embodiments from the first embodiment to the eight embodiment can be combined voluntarily. Thus, the present invention can have various modifications which fairly fall within the basic teachings herein set forth.

[0122] Thus, an optical encoder according to the present invention is a reflecting triple grating type encoder. Alight transparent member is disposed in a space between a surface of a detecting head and a first grating, and in a space between the surface of the detecting head and a third grating. Accordingly, it is possible to relax a tolerance of ∆zd corresponding to a refractive index of the light transparent member. As a result of this, it is possible to realize a tolerance which makes the manufacturing easy, and to provide a triple grating type optical encoder which can be mass produced at a low cost.

[0123] Thus, the optical encoder according to the present invention is useful for the reflecting triple grating type optical encoder in which the tolerance between the structure members is relaxed.

Claims

1. An optical encoder comprising:

a scale (121) which is installed on one of members of which a displacement is detected; and
a detecting head (130, 131, 150, 190, 111, 141) which is installed on other member which is displaced relatively with respect to the one of the members, and which is disposed facing the scale (121), wherein
the scale (121) is provided with a second grating (120) which has an optical pattern of a second pitch (p2) with respect to a direction of a relative displacement, and
the detecting head (130, 131, 150, 190, 111, 141) is provided with
a light projecting section (110, 141) which irradiates a predetermined light on the scale (121), and
a photodetecting section (130, 150) which detects a movement of a self image which is formed on a light receiving surface of a photodetector (150) by light which is irradiated from the light projecting section (110, 141) to the scale (121), and which is reflected and diffracted by the second grating (120), wherein
the light projecting section (110, 141) is structured to irradiate the predetermined light by combining a light source (141) and a first grating (110) which is disposed on a side facing the scale (121) with respect to the light source (141), and
the first grating (110) is an optical grating formed by a first pitch (p1) with respect to the direction of the relative displacement, and
the photodetecting section (130, 150) is structured to detect the movement of the self image by combining the photodetector (150) and a third grating (130) which is disposed on the light receiving surface of the photodetector (150), and
the third grating (130) is an optical grating formed by a third pitch (p3) with respect to the direction of the relative displacement, and
each of a formation surface of the first grating (110), a formation surface of the third grating (130), and the light receiving surface is disposed substantially parallel with respect to the scale (121), and
in an optical path of light emitting from the light projecting section (110, 141) and reaching up to the photodetecting section (130, 150) upon being reflected and diffracted by the scale (121), a light transmitting area which is substantially flat and substantially parallel to the scale (121) is formed on a surface of the detecting head (130, 131, 150, 190, 111, 141) facing the scale (121), and

the first grating (110) is formed apart from the third grating (130) and directly formed on a light emitting surface of the light source (141) between the light source (141) and a light transparent substrate (111), and
the third grating (130) is disposed between the photodetector (150) and a light transparent substrate (131),
a light transparent resin (190) which has a refractive index greater than 1 is disposed in a space from the first grating (110) up to the surface of the detecting head (130, 131, 150, 190, 111, 141), and in a space from the third grating (130) up to the surface of the detecting head (130, 131, 150, 190, 111, 141), except in a space where the light transparent substrates (111, 131) is disposed.

2. The optical encoder according to claim 1, wherein the third grating (130) is directly formed on the light receiving surface of the photodetector (150).

3. The optical encoder according to claim 2, wherein the first grating (110) is an electrode pattern which also serves as an electric current injecting electrode of the light source (141).

4. The optical encoder according to claim 2, wherein the light source (141) is a bare chip or a surface emitting semiconductor device in which the bare chip is seal-molded.

5. The optical encoder according to claim 2, wherein:

at least one of the first grating and the third grating is formed in the respective light transparent substrate (111, 131); and
a side surface of the respective light transparent substrate (111, 131) is covered by the light transparent resin (190).

6. The optical encoder according to claim 2, wherein

a light transparent member (105) in a form of a plate disposed parallel to the scale (121) is disposed on a side facing the scale (121) with respect to the first grating (110) and the third grating (130), and
one of the respective light transparent substrate (111, 131) and the light transparent resin (190) is disposed in a space between the light transparent member (105) in the form of a plate and the first grating (110), and in a space between the light transparent member (105) in the form of a plate and the third grating (130).

7. The optical encoder according to claim 1, wherein:

the photodetecting section (130, 150) is structured by at least one light receiving element array (151) which is formed with a pitch (p3) constituting a third grating (130) and which is disposed on the light receiving surface of the photodetector (150), and
the light receiving element array (151) includes light receiving elements (Pd_i) having a pitch of substantial integral multiples of a periodic intensity distribution of the self image.

8. The optical encoder according to claim 7, wherein the first grating (110) is an electrode pattern which also serves as an electric current injecting electrode of the light source (141).

9. The optical encoder according to claim 7, wherein the light source (141) is one of a bare chip and a surface emitting semiconductor device in which the bare chip is seal-molded.

10. The optical encoder according to claim 7, wherein the first grating (110) is formed in the light transparent substrate (111), and a side surface of the light transparent substrate (111) is covered by the light transparent resin (190).

11. The optical encoder according to claim 7, wherein:

a light transparent member (105) in a form of a plate disposed parallel to the scale (121) is disposed on a side facing the scale (121) with respect to the first grating (110) and the light receiving surface, and
one of the corresponding light transparent substrates (111, 131) and the light transparent resin (190) is disposed in a space between the light transparent member (105) in the form of a plate and the first grating (110), and in a space between the light transparent member (105) in the form of a plate and the light receiving surface.

12. The optical encoder according to claim 2, wherein at least one of a light transparent member (105) in a form of a plate, the light transparent substrates (111, 131), and the light transparent resin (190) has a predetermined optical transmittance with respect to a predetermined wavelength region in which a light from the light source (141) is emitted, and the optical transmittance is not greater than 1/2 with respect to wavelenghts other than the wavelenghts of the light source (141).

13. The optical encoder according to claim 2, wherein a refractive index of the light transparent resin (190) is not less than 1.4 in a central wavelength of a light emitted from the light source (141).

14. The optical encoder according to claim 7, wherein at least one of a iight transparent member (105) in a form of a plate, the light transparent substrates (111, 131), and the light transparent resin (190) has a predetermined optical transmittance with respect to a predetermined wavelength region in which a light from the light source (141) is emitted, and the optical transmittance is not greater than 1/2 with respect to wavelangths other than the wavelengths of the light source (141).

15. The optical encoder according to claim 7, wherein a refractive index of the light transparent resin (190) is not less than 1.4 in a central wavelength of a light emitted from the light source (141).

Patentansprüche

1. Optische Kodiereinrichtung mit:

einem Maßstab (121), der auf einem von Elementen angebracht ist, dessen Verschiebung erfasst wird; und
einem Erfassungskopf (130, 131, 150, 190, 111, 141), der auf einem weiteren Element angebracht ist, das relativ zu dem einen der Elemente verschoben wird und das gegenüber dem Maßstab (121) angeordnet ist, wobei der Maßstab (121) ein zweites Gitter (120) aufweist, das ein optisches Muster mit einer zweiten Gitterkonstante (p2) bezüglich einer Richtung einer relativen Verschiebung besitzt, und
der Erfassungskopf (130, 131, 150, 190, 111, 141) umfasst:

einen Lichtprojektionsabschnitt (110, 141), der ein vorbestimmtes Licht auf den Maßstab (121) strahlt, und
einen Fotoerfassungsabschnitt (130, 150), der eine Bewegung eines Selbstbildes erfasst, das auf einer Lichtempfangsoberfläche eines Fotodetektors (150) durch Licht gebildet wird, das von dem Lichtprojektionsabschnitt (110, 141) zu dem Maßstab (121) gestrahlt wird und das durch das zweite Gitter (120) reflektiert und gebeugt wird, wobei
der Lichtprojektionsabschnitt (110, 141) so aufgebaut ist, dass er das vorbestimmte Licht ausstrahlt, indem er eine Lichtquelle (141) und ein erstes Gitter (110), das auf einer dem Maßstab (121) gegenüberliegenden Seite bezüglich der Lichtquelle (141) angeordnet ist, und
das erste Gitter (110) ein optisches Gitter ist, das durch eine erste Gitterkonstante (p1) bezüglich der Richtung der relativen Verschiebung gebildet ist, und
der Fotoerfassungsabschnitt (130, 150) so aufgebaut ist, dass er die Bewegung des Selbstbildes durch Kombinieren des Fotodetektors (150) mit einem dritten Gitter (130), das auf der Lichtempfangsoberfläche des Fotodetektors (150) angeordnet ist, erfasst, und
das dritte Gitter (130) ein optisches Gitter ist, das durch eine dritte Gitterkonstante (p3) bezüglich der Richtung der relativen Verschiebung gebildet ist, und
sowohl eine Bildungsoberfläche des ersten Gitters (110) als auch eine Bildungsoberfläche des dritten Gitters (130) als auch eine Lichtempfangsoberfläche im Wesentlichen parallel bezüglich des Maßstabs (121) angeordnet ist, und
in einem Lichtweg eines Lichts, das von dem Lichtprojektionsabschnitt (110, 141) ausgesendet wird und den Fotoerfassungsabschnitt (130, 150) erreicht, nachdem es durch den Maßstab (121) reflektiert und gebeugt wurde, ein Lichtdurchlassbereich, der im Wesentlichen flach und im Wesentlichen parallel zu dem Maßstab (121) ist, auf einer Oberfläche des Erfassungskopfes (130, 131, 150, 190, 111, 141), dem Maßstab (121) gegenüberliegend ausgebildet ist, und
das erste Gitter (110) in einem Abstand zu dem dritten Gitter (130) ausgebildet ist und direkt auf einer Lichtaussendeoberfläche der Lichtquelle (141), zwischen der Lichtquelle (141) und einem lichtdurchlässigen Substrat (111) angeordnet ist, und
das dritte Gitter (130) zwischen dem Fotodetektor (150) und einem lichtdurchlässigen Substrat (131) angeordnet ist,
ein lichtdurchlässiges Harz (190), das einen Brechungsindex größer 1 besitzt, in einem Raum von dem

ersten Gitter (110) bis zu der Oberfläche des Erfassungskopfes (130, 131, 150, 190, 111, 141) und in einem Raum von dem dritten Gitter (130) bis zu der Oberfläche des Erfassungskopfes (130, 131, 150, 190, 111, 141), außer in einem Raum, in dem die lichtdurchlässigen Substrate (111, 131) angeordnet ist, angeordnet ist.

2. Optische Kodiereinrichtung nach Anspruch 1, wobei das dritte Gitter (130) direkt auf der Lichtempfangsoberfläche des Fotodetektors (150) ausgebildet ist.

3. Optische Kodiereinrichtung nach Anspruch 2, wobei das erste Gitter (110) ein Elektrodenmuster ist, das auch als eine Elektrode der Lichtquelle (141) zur Einspeisung eines elektrischen Stroms dient.

4. Optische Kodiereinrichtung nach Anspruch 2, wobei die Lichtquelle (141) ein leerer Chip oder eine oberflächenemittierende Halbleitervorrichtung, in die der leere Chip eingegossen ist, ist.

5. Optische Kodiereinrichtung nach Anspruch 2, wobei:

wenigstens entweder das erste Gitter oder das dritte Gitter in dem jeweiligen lichtdurchlässigen Substrat (111, 131) ausgebildet ist; und
eine seitliche Oberfläche des jeweiligen lichtdurchlässigen Substrats (111, 131) von einem lichtdurchlässigen Harz (190) bedeckt ist.

6. Optische Kodiereinrichtung nach Anspruch 2, wobei:

ein lichtdurchlässiges Element (105) in Form einer parallel zu dem Maßstab (121) angeordneten Platte auf einer bezüglich des ersten Gitters (110) und der Lichtempfangsoberfläche gegenüberliegenden Seite des Maßstabs (121) angeordnet ist, und
entweder das jeweilige lichtdurchlässige Substrat (111, 131) oder das lichtdurchlässige Harz (190) in einem Raum zwischen dem lichtdurchlässigen Element (105) in der Form einer Platte und dem ersten Gitter (110) und in einem Raum zwischen dem lichtdurchlässigen Element (105) in der Form einer Platte und dem dritten Gitter (130) angeordnet ist.

7. Optische Kodiereinrichtung nach Anspruch 2, wobei:

der Fotoerfassungsabschnitt (130, 150) aus wenigstens einem Feld (151) aus Lichtempfangselementen aufgebaut ist, das eine Gitterkonstante (p3) aufweist, die ein drittes Gitter (130) bildet, und das auf der Lichtempfangsoberfläche des Fotodetektors (150) angeordnet ist, und
das Feld (151) aus Lichtempfangselementen Lichtempfangselemente (Pd_i) mit einer Gitterkonstante, die im Wesentlichen ein ganzzahliges Vielfaches einer periodischen Intensitätsverteilung des Selbstbildes ist, umfasst.

8. Optische Kodiereinrichtung nach Anspruch 7, wobei das erste Gitter (110) ein Elektrodenmuster ist, das auch als Elektrode der Lichtquelle (141) zur Einspeisung eines elektrischen Stroms dient.

9. Optische Kodiereinrichtung nach Anspruch 7, wobei die Lichtquelle (141) ein leerer Chip oder eine oberflächenemittierende Halbleitervorrichtung, in die der leere Chip eingegossen ist, ist.

10. Optische Kodiereinrichtung nach Anspruch 7, wobei das erste Gitter (110) in dem lichtdurchlässigen Substrat (111) ausgebildet ist und eine seitliche Oberfläche des lichttransparenten Substrats (111) von dem lichtdurchlässigen Harz (190) bedeckt ist.

11. Optische Kodiereinrichtung nach Anspruch 7, wobei:

ein lichtdurchlässiges Element (105) in Form einer parallel zu dem Maßstab (121) angeordneten Platte auf einer bezüglich des ersten Gitters (110) und der Lichtempfangsoberfläche gegenüberliegenden Seite des Maßstabs (121) angeordnet ist, und
entweder das entsprechende lichtdurchlässige Substrat (111, 131) oder das lichtdurchlässige Harz (190) in einem Raum zwischen dem lichtdurchlässigen Element (105) in der Form einer Platte und dem ersten Gitter (110) und in einem Raum zwischen dem lichtdurchlässigen Element (105) in der Form einer Platte und der Lichtempfangsoberfläche angeordnet ist.

12. Optische Kodiereinrichtung nach Anspruch 2, wobei wenigstens entweder ein lichtdurchlässiges Element (105) in Form einer Platte, die lichtdurchlässigen Substrate (111, 131) oder das lichtdurchlässige Harz (190) einen vorbestimmten optischen Transmissionsgrad bezüglich eines vorbestimmten Wellenlängenbereichs besitzt, in dem ein Licht von der Lichtquelle (141) ausgesendet wird, und der optische Transmissionsgrad nicht größer als 1/2 bezüglich von den Wellenlängen der Lichtquelle (141) verschiedenen Wellenlängen ist.

13. Optische Kodiereinrichtung nach Anspruch 2, wobei ein Brechungsindex des lichtdurchlässigen Harzes (190) bei einer mittleren Wellenlänge eines von der Lichtquelle (141) ausgesendeten Lichts nicht kleiner als 1,4 ist.

14. Optische Kodiereinrichtung nach Anspruch 7, wobei wenigstens entweder ein lichtdurchlässiges Element (105) in Form einer Platte, die lichtdurchlässigen Substrate (111, 131) oder das lichtdurchlässige Harz (190) einen vorbestimmten optischen Transmissionsgrad bezüglich eines vorbestimmten Wellenlängenbereichs besitzt, in dem ein Licht von der Lichtquelle (141) ausgesendet wird, und der optische Transmissionsgrad nicht größer als 1/2 bezüglich von den Wellenlängen der Lichtquelle (141) verschiedenen Wellenlängen ist.

15. Optische Kodiereinrichtung nach Anspruch 7, wobei ein Brechungsindex des lichtdurchlässigen Harzes (190) bei einer mittleren Wellenlänge eines von der Lichtquelle (141) ausgesendeten Lichts nicht kleiner als 1,4 ist.

Revendications

1. Encodeur optique, comprenant :

un plateau (121) qui est installé sur un parmi des éléments dont un déplacement est détecté ; et
une tête de détection (130, 131, 150, 190, 111, 141) qui est installée sur un autre élément qui est déplacé relativement par rapport l'un parmi les éléments, et qui est disposé en face du plateau (121), dans lequel
le plateau (121) est pourvu d'un deuxième réseau (120) qui comporte un motif optique d'un deuxième pas (p2) par rapport à une direction d'un déplacement relatif, et
la tête de détection (130, 131, 150, 190, 111, 141) est pourvue d'une section de projection de lumière (110, 141) qui rayonne une lumière prédéterminée sur le plateau (121), et
une section de photodétection (130, 150) qui détecte un mouvement d'une auto-image qui est formée sur une surface de réception de lumière d'un photodétecteur (150) par de la lumière qui est rayonnée à partir de la section de projection de lumière (110, 141) au plateau (121), et qui est réfléchie et diffractée par le deuxième réseau (120), dans lequel
la section de projection de lumière (110, 141) est structurée pour rayonner la lumière prédéterminée en combinant une source de lumière (141) et un premier réseau (110) qui est disposé sur un côté faisant face au plateau (121) par rapport à la source de lumière (141), et
le premier réseau (110) est un réseau optique formé par un premier pas (p1) par rapport à la direction du déplacement relatif, et
la section de photodétection (130, 150) est structurée pour détecter le mouvement de l'auto-image en combinant le photodétecteur (150) et un troisième réseau (130) qui est disposé sur la surface de réception de lumière du photodétecteur (150), et le troisième réseau (130) est un réseau optique formé par un troisième pas (p3) par rapport à la direction du déplacement relatif, et
chacune parmi une surface de formation du premier réseau (110), une surface de formation du troisième réseau (130), et la surface de réception de lumière est disposée de façon sensiblement parallèle par rapport au plateau (121), et
dans un trajet optique de lumière émise à partir de la section de projection de lumière (110, 141) et atteignant la section de photodétection (130, 150), lorsqu'elles est réfléchie et diffractée par le plateau (121), une zone de transmission de lumière qui est sensiblement plate et sensiblement parallèle au plateau (121) est formée sur une surface de la tête de détection (130, 131, 150, 190, 111, 141) faisant face au plateau (121), et
le premier réseau (110) est formé de façon séparée du troisième réseau (130) et directement formé sur une surface d'émission de lumière de la source de lumière (141) entre la source de lumière (141) et un substrat transparent à la lumière (111), et
le troisième réseau (130) est disposé entre le photodétecteur (150) et un substrat transparent à la lumière (131), une résine transparente à la lumière (190) qui comporte un indice de réfraction supérieur à 1 est disposé dans un espace à partir du premier réseau (110) jusqu'à la surface de la tête de détection (130, 131, 150, 190, 111, 141), et dans un espace à partir du troisième réseau (130) jusqu'à la surface de la tête de détection (130, 131, 150, 190, 111, 141), sauf dans un espace où les substrats transparents à la lumière (111, 131) sont disposés.

2. Encodeur optique selon la revendication 1, dans lequel le troisième réseau (130) est directement formé sur la surface de réception de lumière du photodétecteur (150).

3. Encodeur optique selon la revendication 2, dans lequel le premier réseau (110) est un motif d'électrode qui sert également d'électrode d'injection de courant électrique de la source de lumière (141).

4. Encodeur optique selon la revendication 2, dans lequel la source de lumière (141) est une puce nue ou un dispositif à semi-conducteur à émission par la surface dans lequel la puce nue est moulée avec scellement.

5. Encodeur optique selon la revendication 2, dans lequel :

le premier réseau et/ou le troisième réseau sont formés dans le substrat respectif transparent à la lumière (111, 131) ; et
une surface latérale du substrat respectif transparent à la lumière (111, 131) est couverte par la résine transparente à la lumière (190).

6. Encodeur optique selon la revendication 2, dans lequel
un élément transparent à la lumière (105) sous forme de plaque disposée parallèlement au plateau (121) est disposé sur un côté faisant face au plateau (121) par rapport au premier réseau (110) et au troisième réseau (130), et
le substrat respectif transparent à la lumière (111, 131) ou la résine transparente à la lumière (190) est disposé dans un espace entre l'élément transparent à la lumière (105) sous forme de plaque et le premier réseau (110), et dans un espace entre l'élément transparent à la lumière (105) sous forme de plaque et le troisième réseau (130).

7. Encodeur optique selon la revendication 1, dans lequel :

la section de photodétection (130, 150) est structurée par au moins une matrice d'éléments de réception de lumière (151) qui est formée avec un pas (p3) constituant un troisième réseau (130) et qui est disposée sur la surface de réception de lumière du photodétecteur (150), et
la matrice d'éléments de réception de lumière (151) comprend des éléments de réception de lumière (Pd_i) possédant un pas de multiples sensiblement entiers d'une distribution d'intensité périodique de l'auto-image.

8. Encodeur optique selon la revendication 7, dans lequel le premier réseau (110) est un motif d'électrode qui sert également d'électrode d'injection de courant électrique de la source de lumière (141).

9. Encodeur optique selon la revendication 7, dans lequel la source de lumière (141) est une puce nue et un dispositif à semi-conducteur à émission par la surface dans lequel la puce nue est moulée avec scellement.

10. Encodeur optique selon la revendication 7, dans lequel le premier réseau (110) est formé dans le substrat transparent à la lumière (111), et une surface latérale du substrat transparent à la lumière (111) est couverte par la résine transparente à la lumière (190).

11. Encodeur optique selon la revendication 7, dans lequel :

un élément transparent à la lumière (105) sous forme de plaque disposée parallèlement au plateau (121) est disposé sur un côté faisant face au plateau (121) par rapport au premier réseau (110) et à la surface de réception de lumière, et
les substrats correspondants transparents à la lumière (111, 131) ou la résine transparente à la lumière (190) sont disposés dans un espace entre l'élément transparent à la lumière (105) sous forme de plaque et le premier réseau (110), et dans un espace entre l'élément transparent à la lumière (105) sous forme de plaque et la surface de réception de lumière.

12. Encodeur optique selon la revendication 2, dans lequel un élément transparent à la lumière (105) sous forme de plaque, et/ou les substrat transparents à la lumière (111, 131), et/ou la résine transparente à la lumière (190) possèdent un facteur de transmission optique prédéterminé par rapport à une région de longueur d'onde prédéterminée dans laquelle une lumière à partir de la source de lumière (141) est émise, et le facteur de transmission optique n'est pas supérieur à 1/2 par rapport à des longueurs d'onde autres que les longueurs d'onde de la source de lumière (141).

13. Encodeur optique selon la revendication 2, dans lequel un indice de réfraction de la résine transparente à la lumière (190) n'est pas inférieur à 1,4 dans une longueur d'onde centrale d'une lumière émise à partir de la source de lumière (141).

14. Encodeur optique selon la revendication 7, dans lequel un élément transparent à la lumière (105) sous forme de plaque, et/ou les substrats transparents à la lumière (111, 131), et/ou la résine transparente à la lumière (190) possèdent un facteur de transmission optique prédéterminé par rapport à une région de longueur d'onde prédéterminée dans laquelle une lumière à partir de la source de lumière (141) est émise, et le facteur de transmission optique n'est pas supérieur à 1/2 par rapport à des longueurs d'onde autres que les longueurs d'onde de la source de lumière (141).

15. Encodeur optique selon la revendication 7, dans lequel un indice de réfraction de la résine transparente à la lumière (190) n'est pas inférieur à 1,4 dans une longueur d'onde centrale d'une lumière émise à partir de la source de lumière (141).

FIG. 1

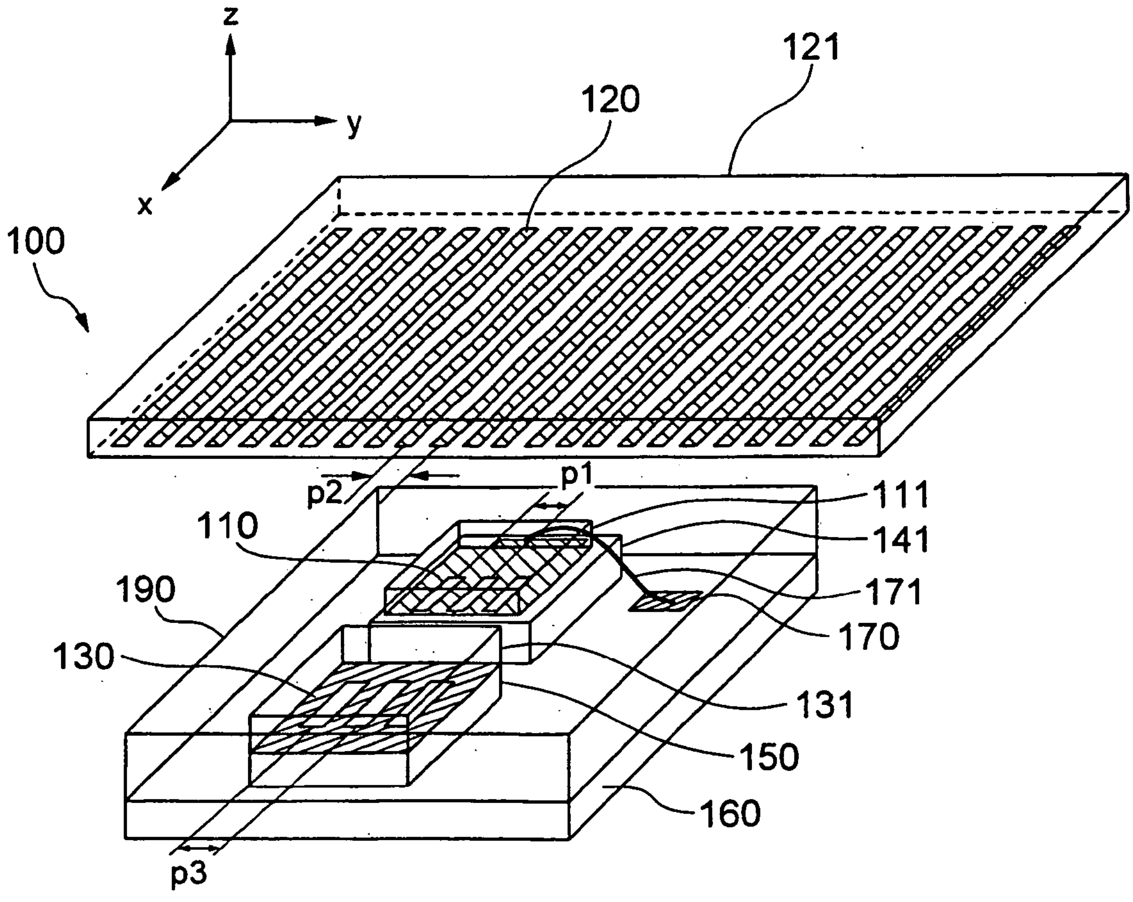


FIG. 2

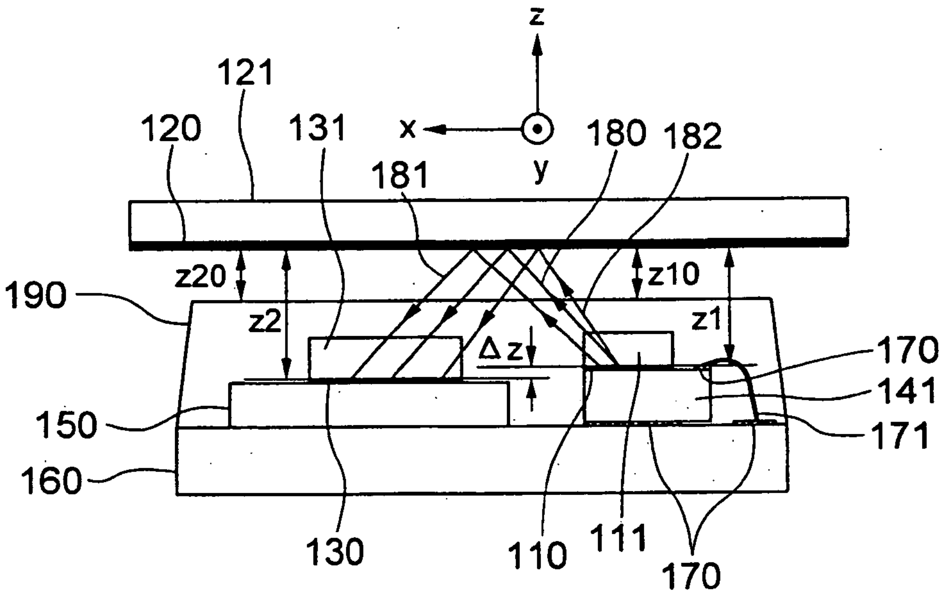

z
x
y
121
120
131
181
180
182
z20
z2
z10
z1
190
Δz
170
141
150
171
160
130
110
111
170

FIG. 3

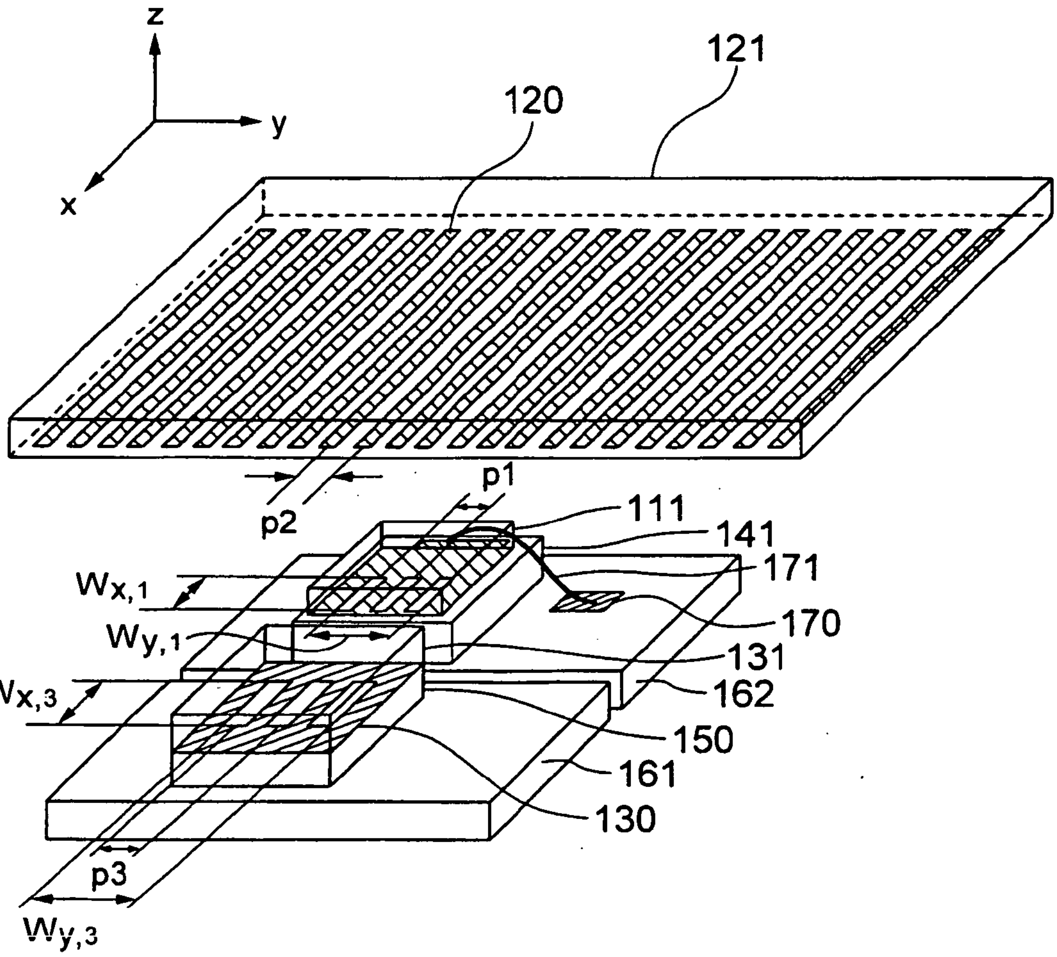

z
y
x
121
120
p2
p1
111
141
171
170
Wx,1
Wy,1
131
162
Wx,3
150
161
130
p3
Wy,3

FIG. 4

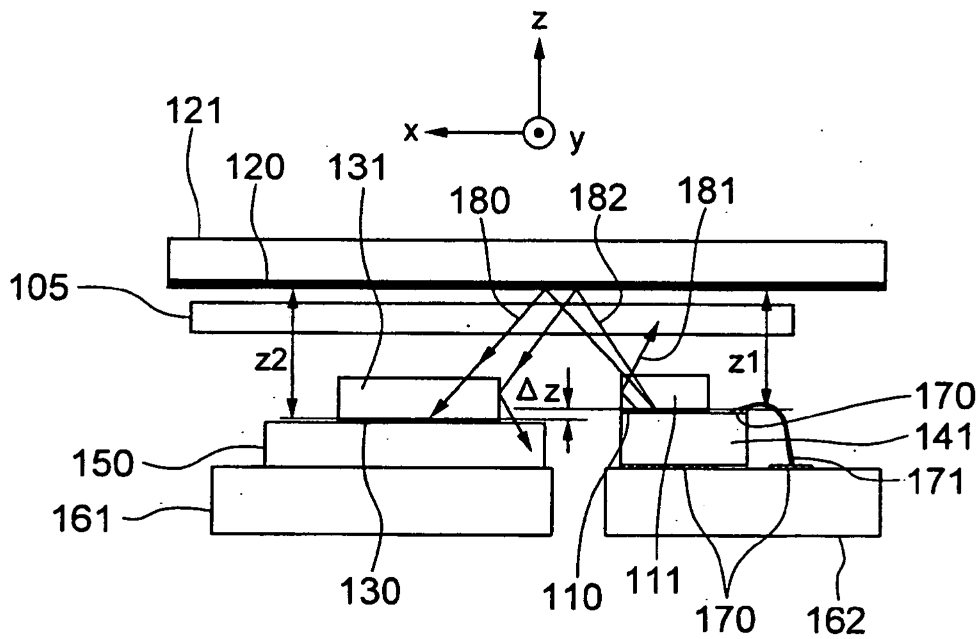

z
x
y
121
120
131
180
182
181
105
z2
Δz
z1
170
141
150
171
161
130
110
111
170
162

FIG. 5

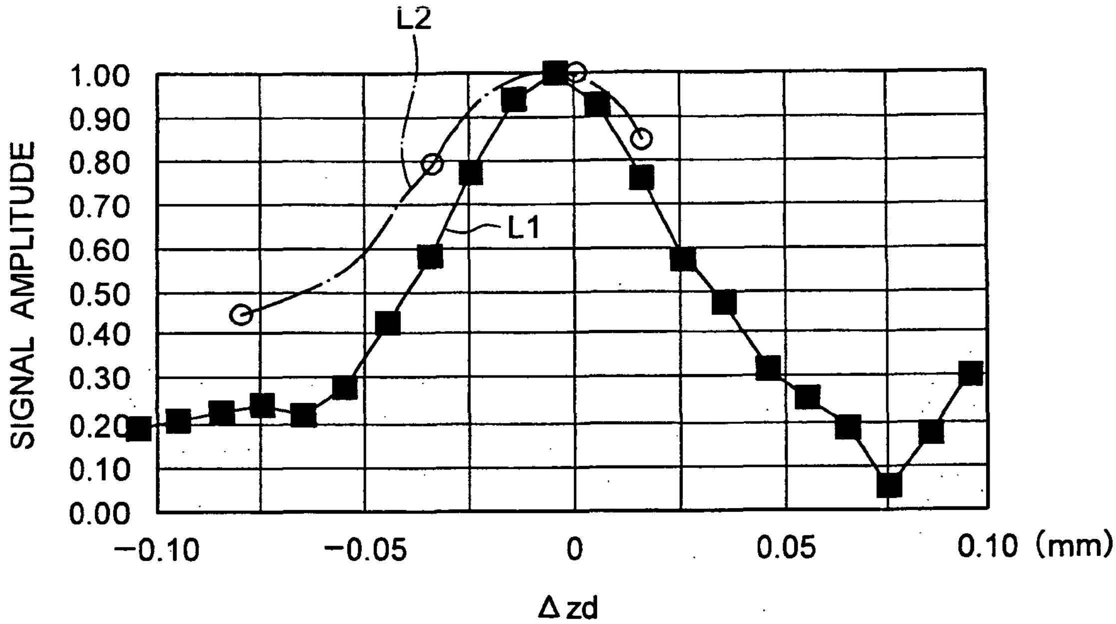

L2
L1
SIGNAL AMPLITUDE
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
−0.10
−0.05
0
0.05
0.10 (mm)
Δ zd

FIG. 6

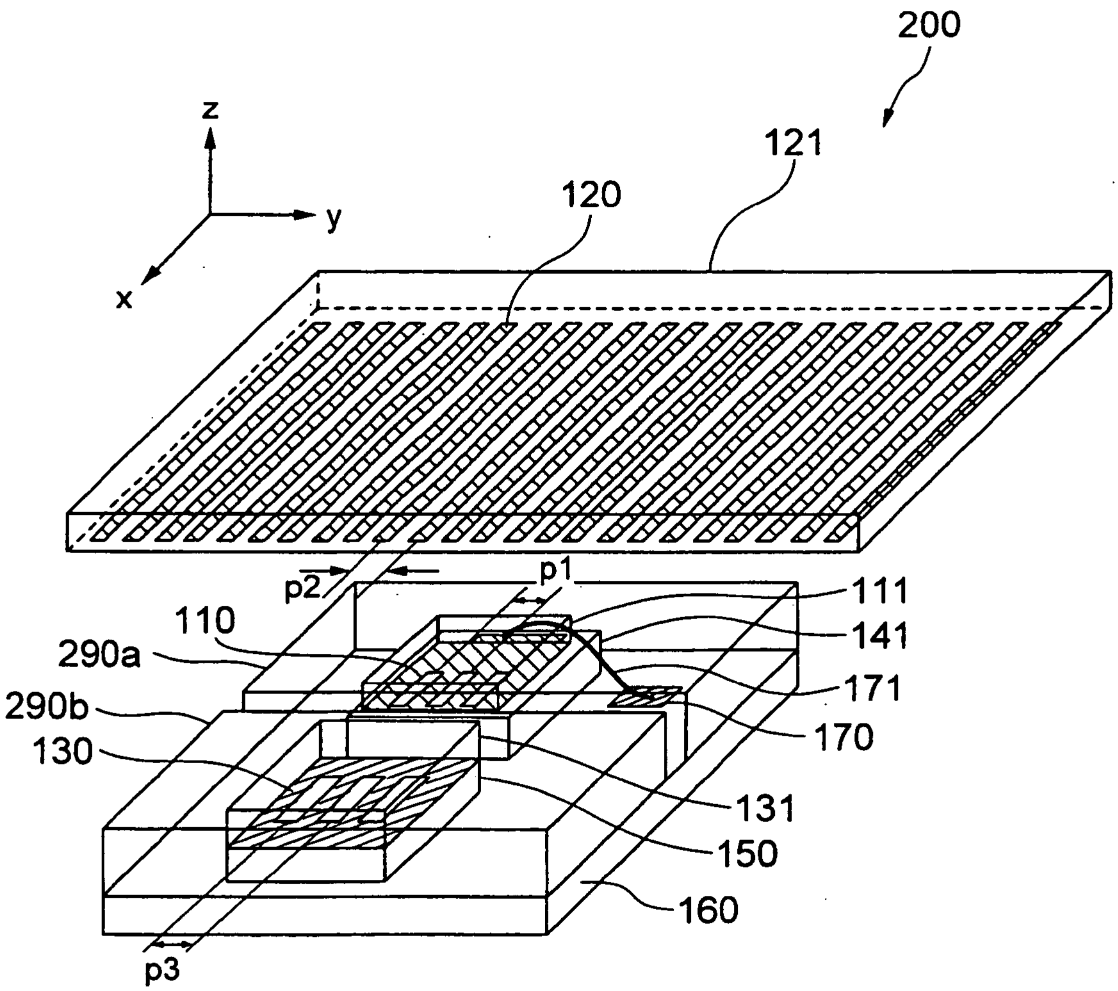

200
z
y
x
121
120
p2
p1
111
110
141
290a
171
290b
170
130
131
150
160
p3

FIG. 7

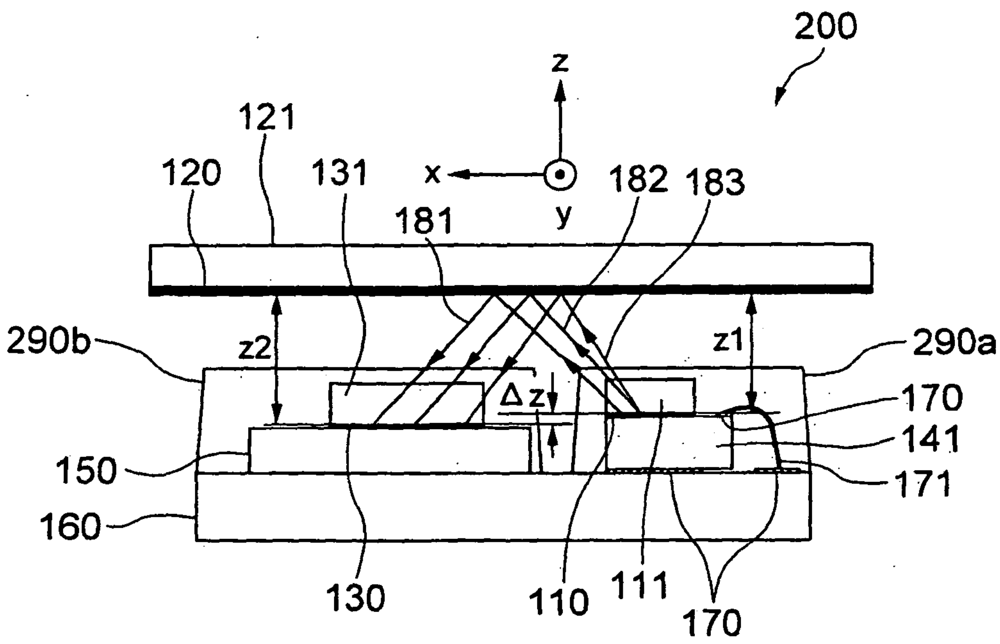

200
z
121
120
131
x
y
182
183
181
290b
z2
z1
290a
Δz
170
141
150
171
160
130
110
111
170

FIG. 8

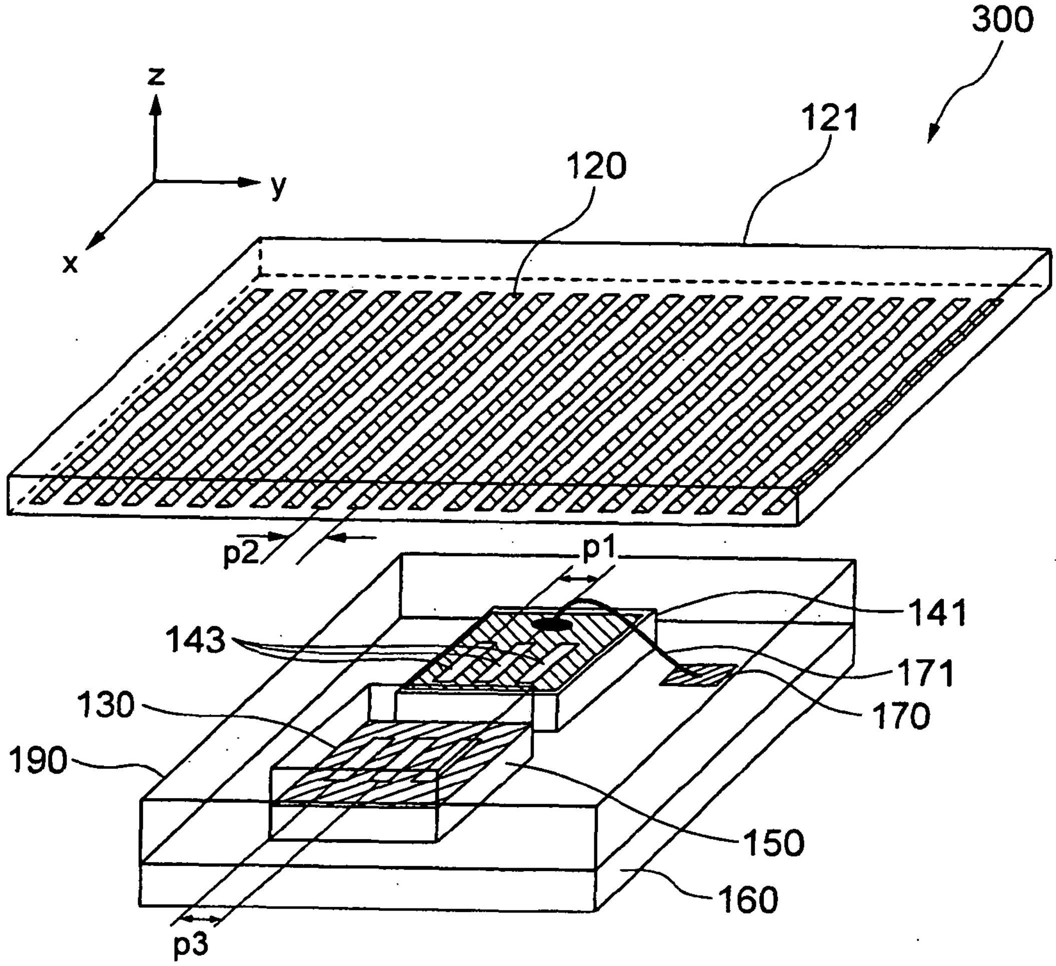


FIG. 9

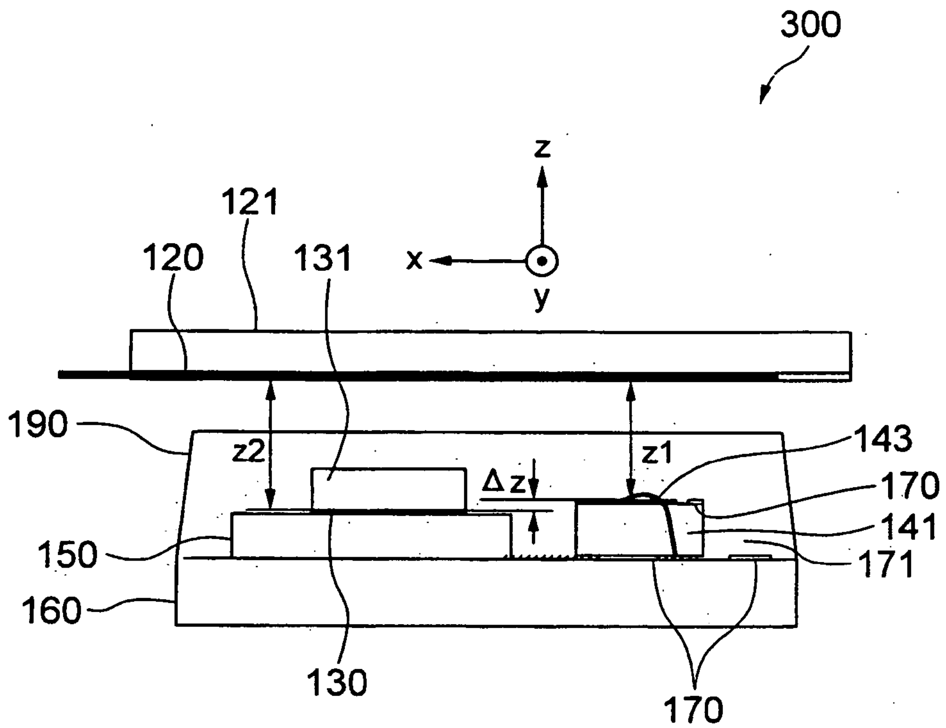
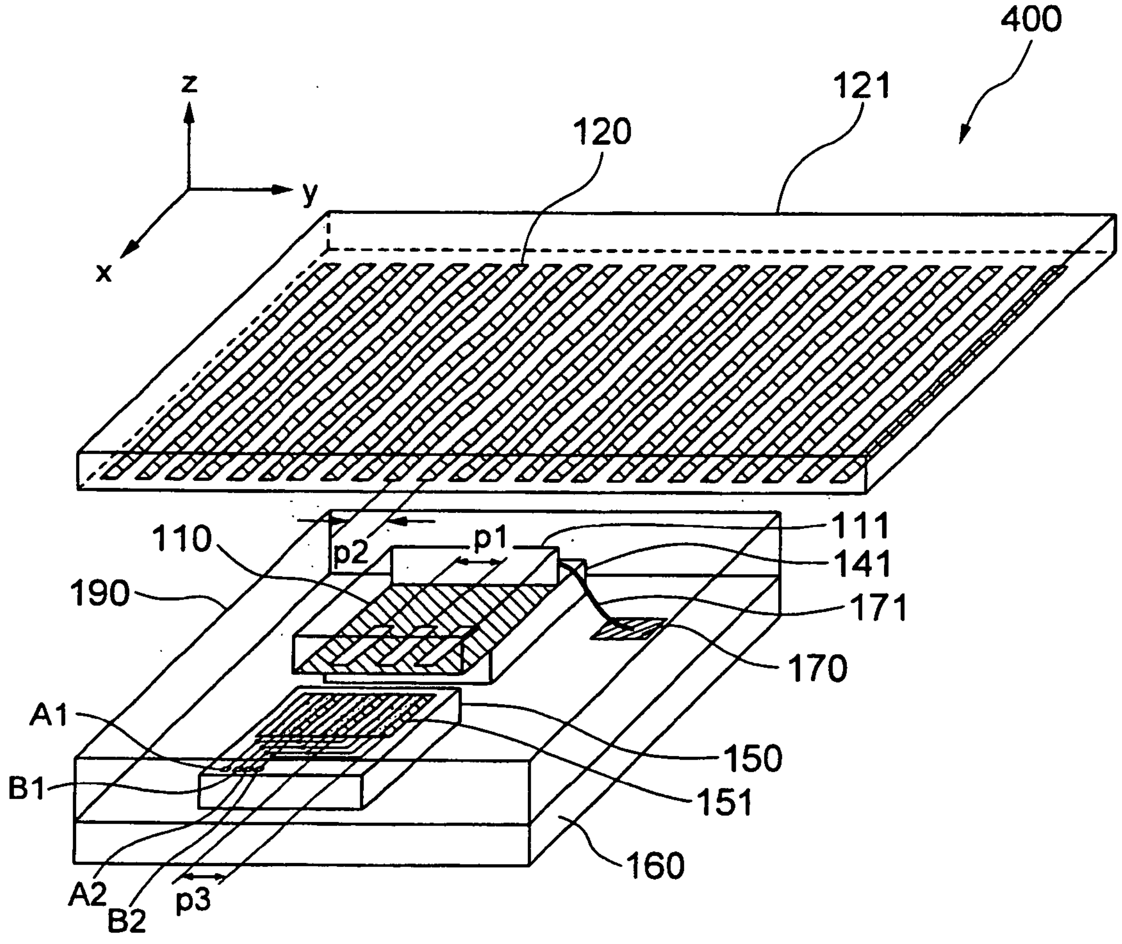


FIG. 10



400
121
120
z
y
x
111
141
171
170
150
151
160
110
190
p2
p1
A1
B1
A2
B2
p3

FIG. 11

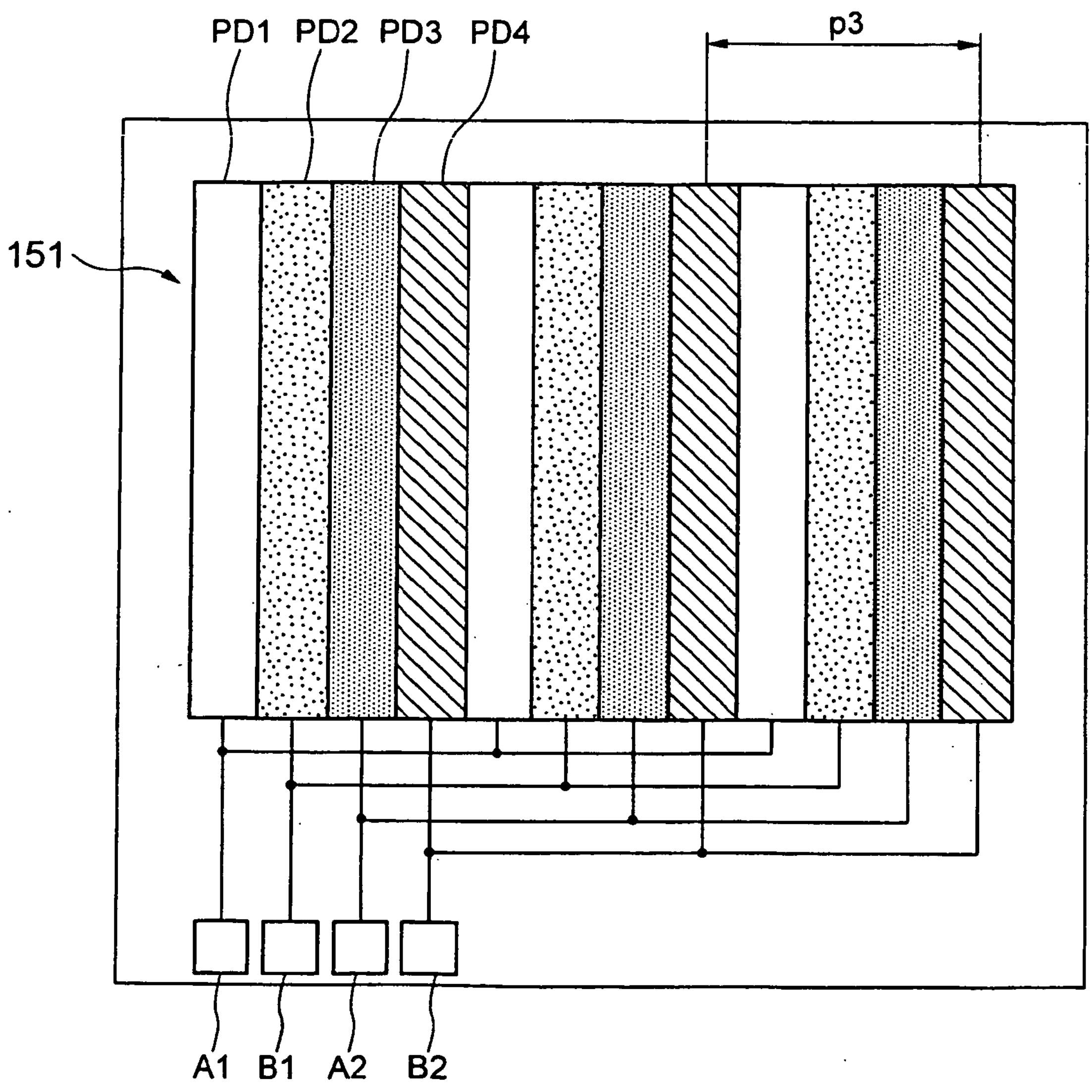


FIG. 12

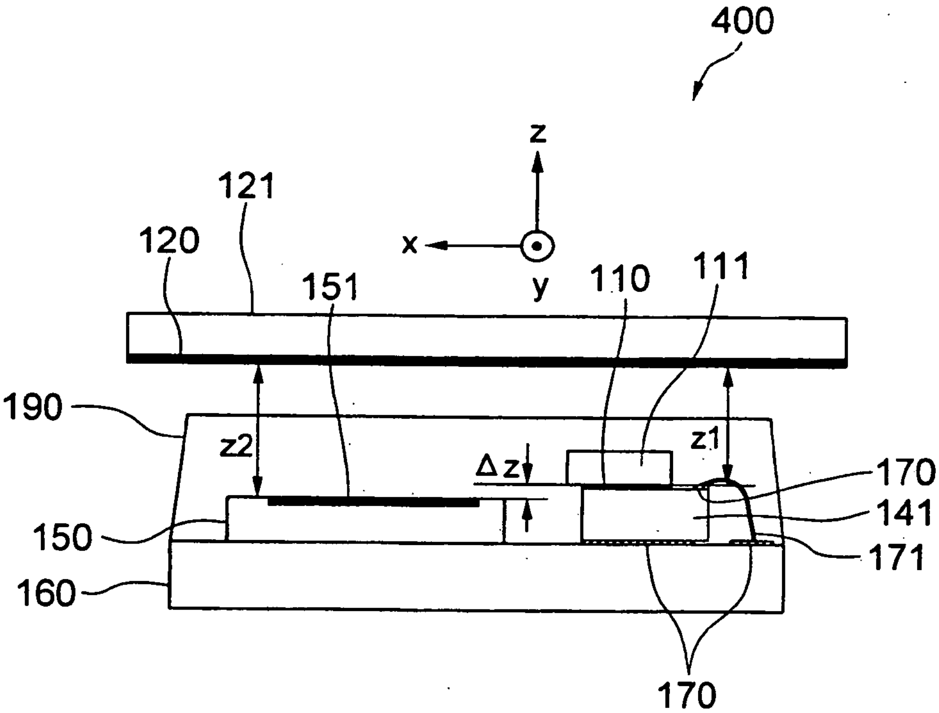


FIG. 13

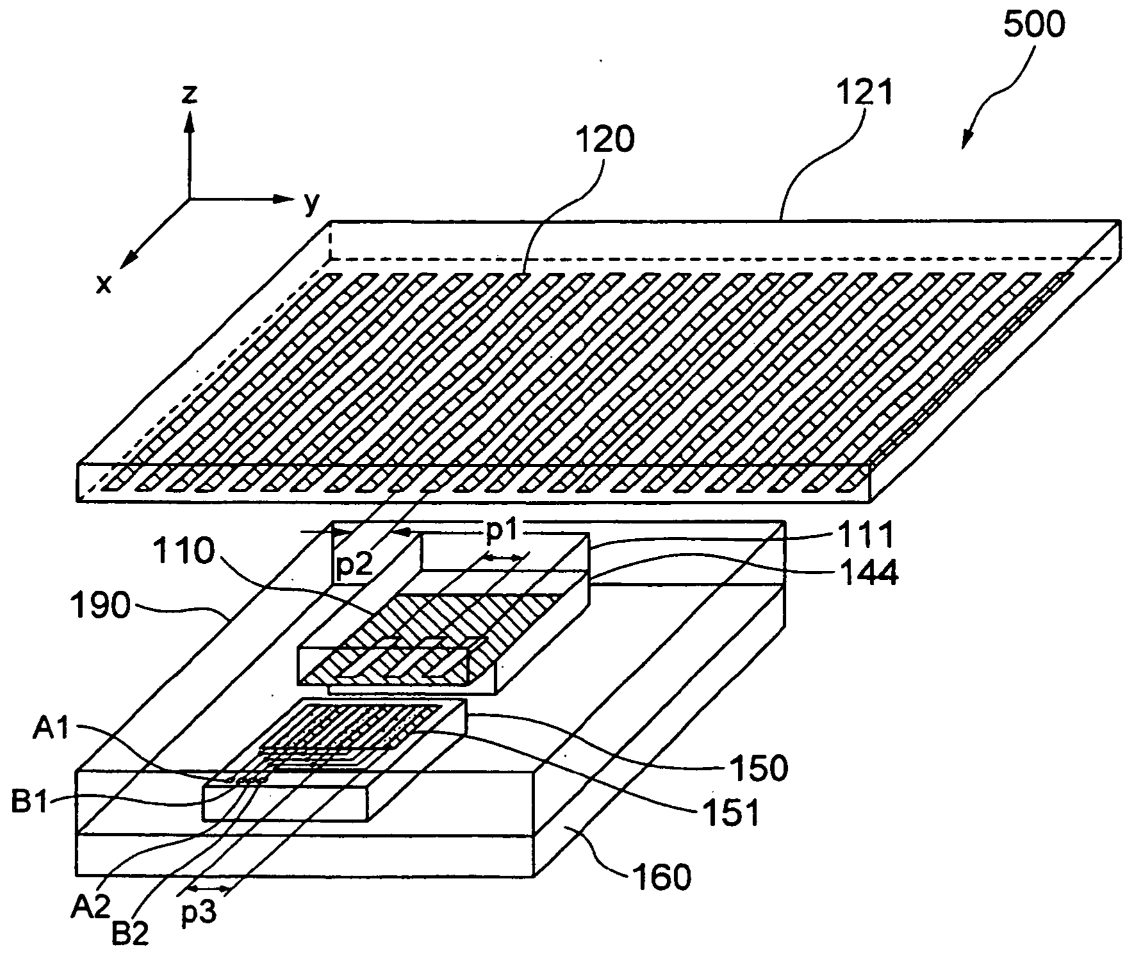


FIG. 14

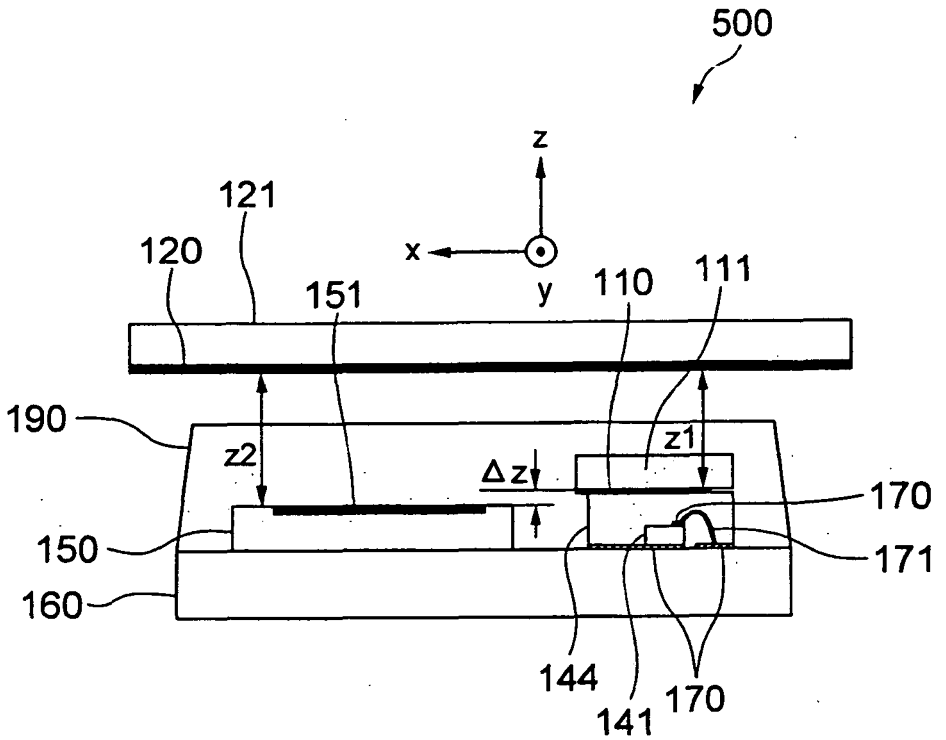

500
z
121
120
x
y
151
110
111
190
z2
z1
Δz
170
150
171
160
144
141
170

FIG. 15

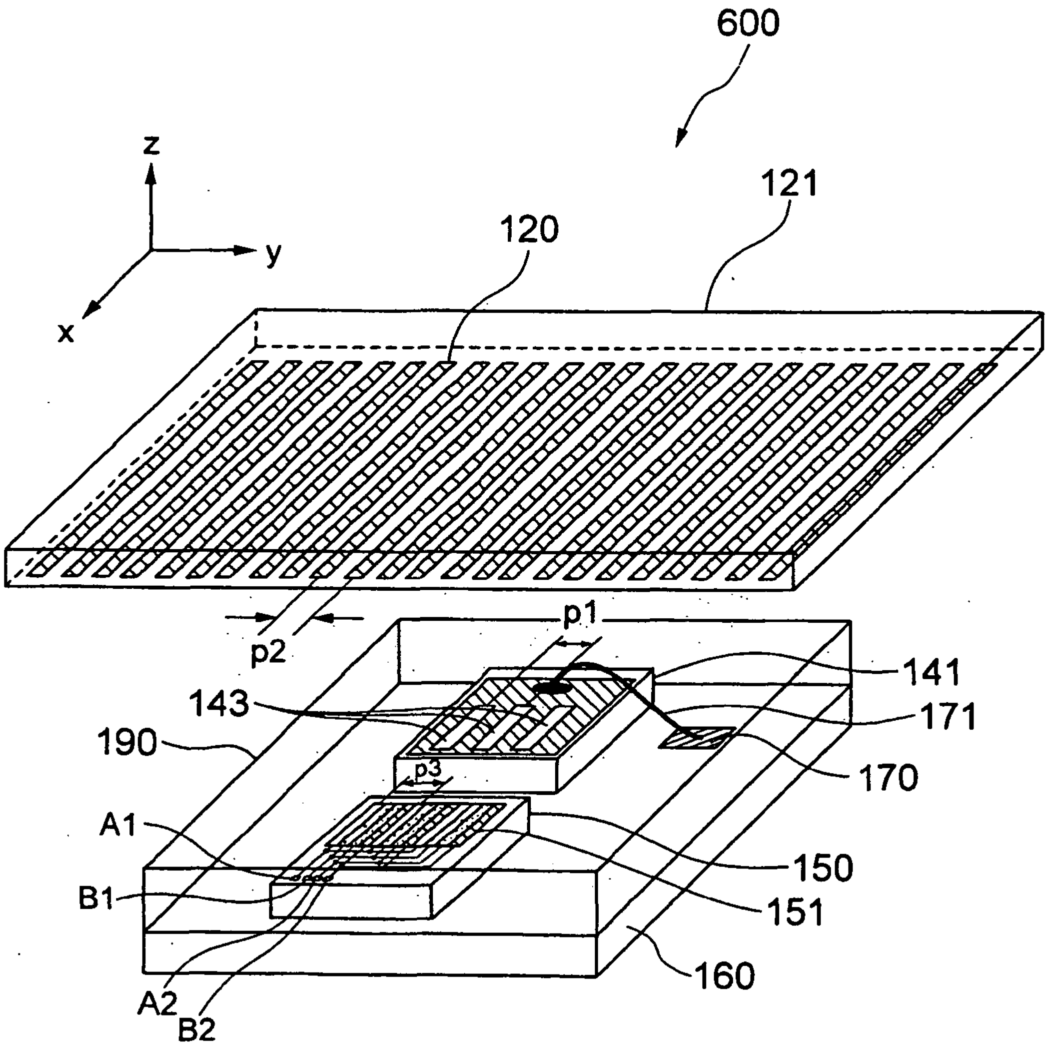

600
z
y
x
121
120
p2
p1
141
143
171
190
170
p3
A1
150
B1
151
160
A2
B2

FIG. 16

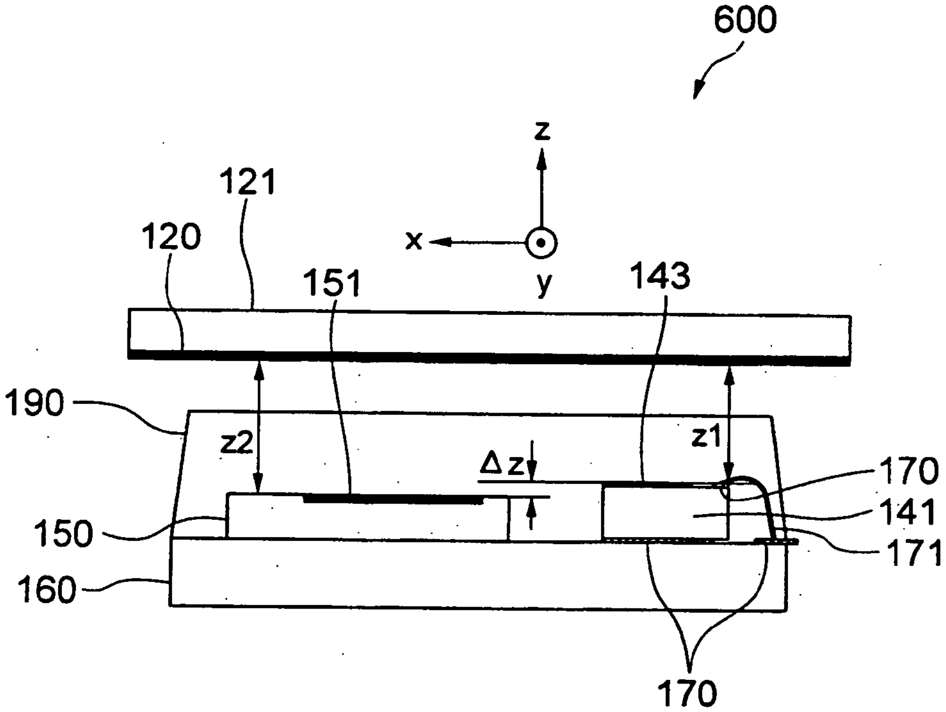


FIG. 17

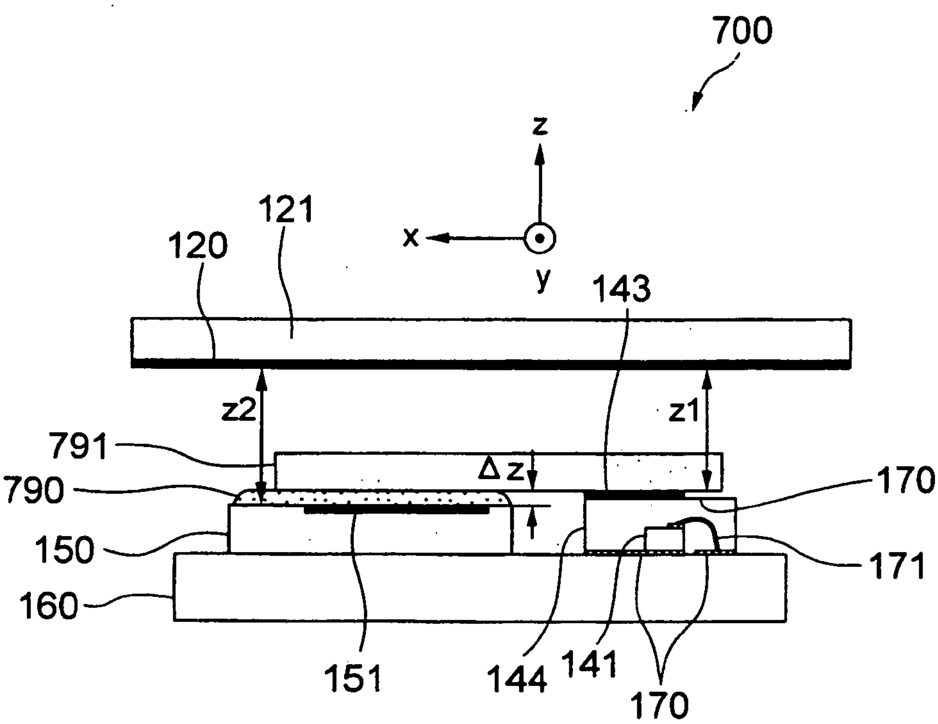

700
z
x
y
121
120
143
z2
z1
791
Δz
790
170
150
171
160
151
144
141
170

FIG. 18

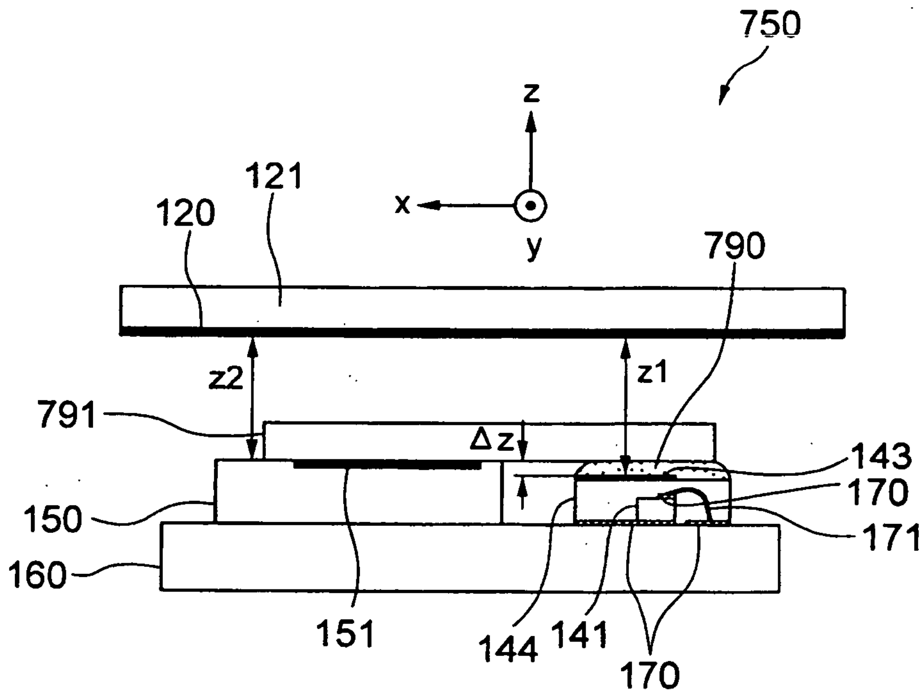

750
z
x
y
121
120
790
z2
z1
791
Δz
143
170
150
171
160
151
144
141
170

FIG. 19

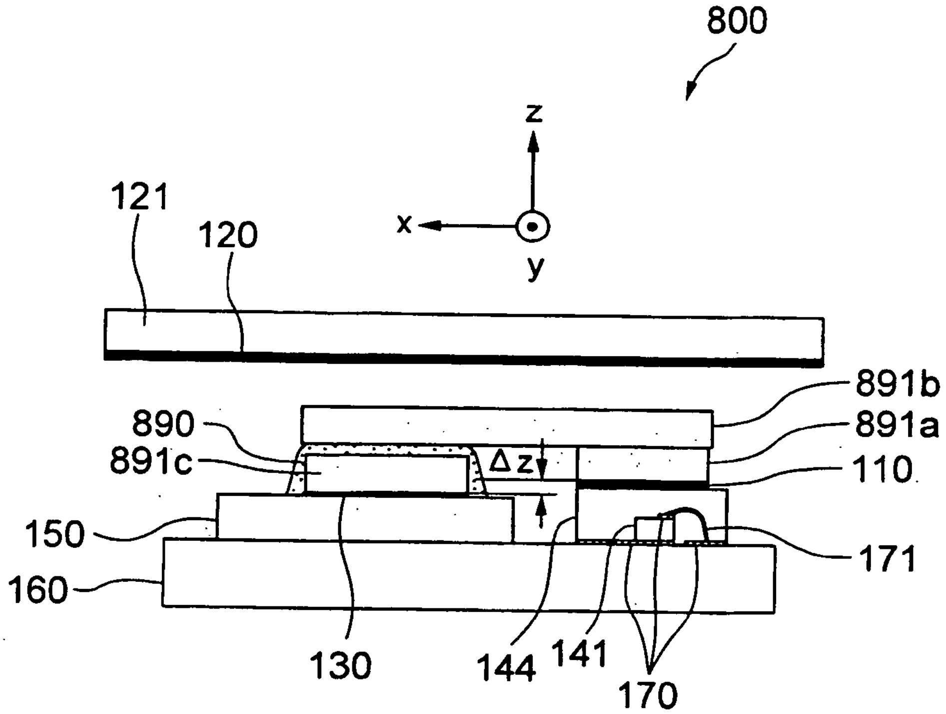

800
z
x
y
121
120
891b
890
891a
891c
Δz
110
150
171
160
130
144
141
170

FIG. 20

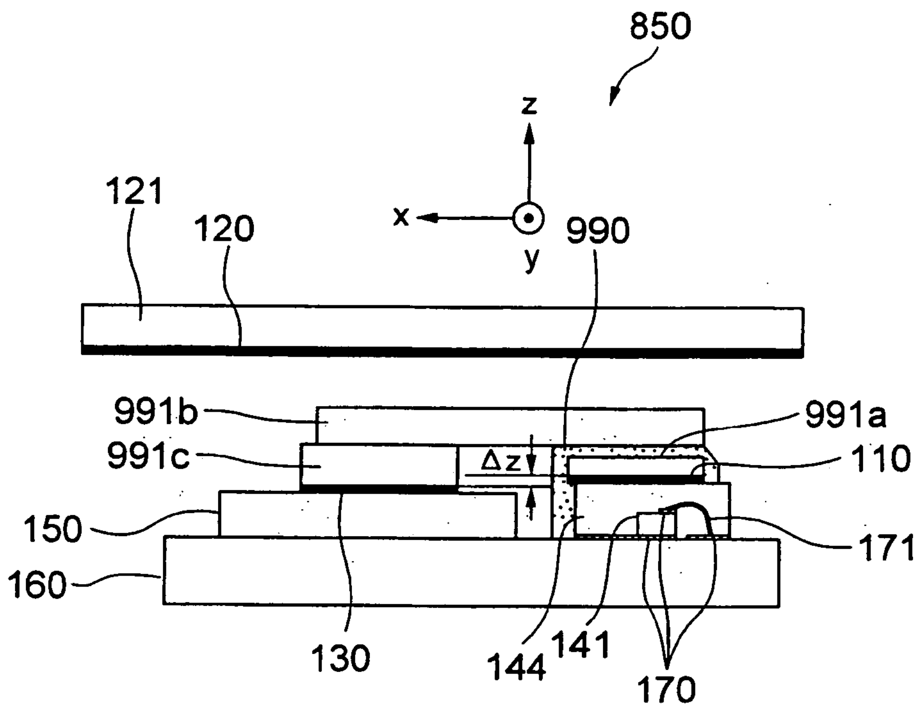
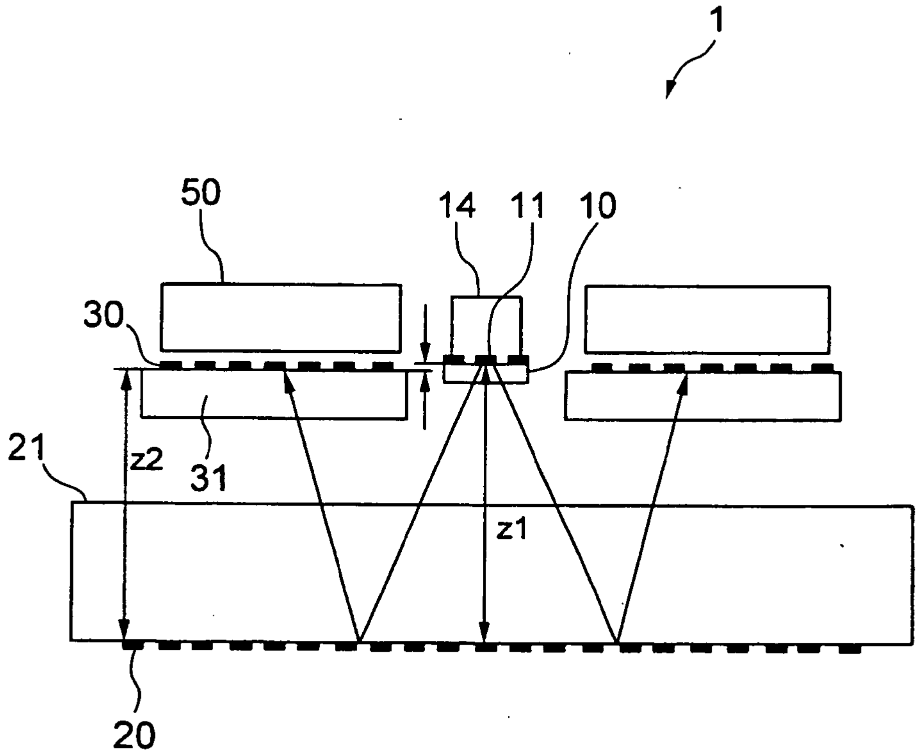

850
z
x
y
121
120
990
991b
991a
991c
Δz
110
150
171
160
130
144
141
170

FIG. 21



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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